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Can a carbon permit system reduce Spanish unemployment?

Abstract:
This paper addresses the frequently articulated worry for the unemployment impacts of abating CO2 emissions. The Spanish economy is ridden by unemployment rates well above the EU average. At the same time the deviation from EU's intermediate emission goals is more serious than for most other EU countries. We use a CGE model that includes a matching model with two types of labour, and which allows for different pricing rules and returns-to-scale assumptions. Our findings are optimistic. Due to low labour intensity in most of the dirty, Spanish industries, the unemployment rate is hardly affected by introducing an emission permit system. Further, by recycling the sales revenue into reduced labour taxes, unemployment rates fall. Contrary to other studies of Europe, we find that reducing payroll taxes on skilled labour is the most successful in reducing unemployment rates, both through increasing demand and through dampening the supply response to rising wages. All the recycling schemes also generate dividends in terms of welfare, but none offset the abatement costs entirely.

Keywords: Spanish unemployment; Tax reform; Emission Permit Auctions; Employment dividend; Matching functions; Increasing returns to scale; Computable general equilibrium models.

JEL classification: D58, J68, Q38.

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1. Introduction

Spain, as part of the EU, has ratified the Kyoto protocol, which aims at reducing greenhouse gas emissions in industrialised countries by 2008-12. Though the burden sharing agreement within EU allows Spain to increase emissions by 15% in this period compared to the 1990 level, a fulfilment of the commitment will require significant reductions compared to a business-as-usual scenario. In fact, by having increased the carbon dioxide (CO_2) emissions by 39.4% from 1990 to 2002, Spain's deviation from EU's intermediate emission goals was more serious than for most other EU countries; see European Environment Agency (2004). As part of the EU emission permit program Spain has introduced revenue-raising emission permits from 2005. There is deep concern for the social costs of such measures. In particular, the debate has focused on the consequences in terms of lost competitiveness and subsequent unemployment. The unemployment problems have been severe since the last part of the 1970s. By the mid 1980s and also by the mid 1990s, the unemployment rate exceeded 20%. In 2002, the average rate had decreased to 11%, with the rate among unskilled labour being the double of that of skilled. Still, this is among the highest unemployment rates in the EU. These facts make Spain special in a European context, and call for detailed studies of this country and its institutions in order to address the economic consequences of carbon policies.

Our aim is to explore whether an auction system for emissions permits is likely to accentuate Spain's serious unemployment problem and how the recycling of sales revenue should be targeted in order to counteract the unemployment effects as effectively as possible. The literature has extensively addressed the possibilities of a *double dividend* from green policies, i.e. economic gains in addition to environmental benefits that may entirely (strong dividends) or partly (weak dividends) offset the costs caused by introducing green tax wedges (Goulder, 1995). Welfare dividends may occur if introducing green taxes or, equivalently, a free market for emission quotas, moderates the welfare losses of other, existing, distortionary taxes, or it may be obtained by using revenues from the green taxation to reduce such tax wedges. For a recent survey, see Schöb (2003). Dividends in terms of employment have also been much in focus, especially in the European debate. Bovenberg and van der Ploeg (1998) discuss the theoretical ambiguity of the scope of employment dividends of emission taxes in presence of structural unemployment, unemployment benefits, endogenous labour supply and revenue recycling. Mors (1995), Majocchi (1996), and Bosquet (2000) all survey quantitative studies, mainly for the EU countries. The costs of green policies are likely to reduce overall economic activity and increase unemployment, unless tax revenues can be targeted towards cutting distortionary taxes on labour. The general empirical conclusion is that there seems to be positive, though small, employment effects of shifting taxes from labour to energy/environment. There is also some evidence of higher employment dividends if measures are targeted to the low skilled. The reasons are that both demand and supply tend to be more elastic in case of unskilled labour. Such a reform was originally proposed as a solution to the European unemployment problem in Dréze and Malinvaud (1994). However, in a Computable General Equilibrium (CGE) analysis where the EU markets for skilled and unskilled labour are separated, Bosello and Carraro (2001) conclude that the employment effects are larger when taxes are reduced for *all* labour rather than for the low skilled, only. As this question is of special interest for Spain, in light of the distributional aspects of the extraordinarily high unemployment of low skilled workers, we include these two proposals in our study. In addition, we supply the analysis with examinations of two other schemes: Recycling revenue through reduced *VAT* rates and through pay roll taxes on skilled labour. In light of the pessimistic employment results in Bosello and Carraro (2001) of targeting to low skilled labour, targeting to the relatively skilled is a natural follow-up research issue.

The tendency in the vast model literature on the double dividend issue is to study welfare effects in a CGE framework that leaves out labour market imperfections, while addressing employment effects in shorter-term econometric models with no consistent measure of welfare changes. In fact, the welfare and employment effects are highly interlinked. Results on employment are important determinants for the welfare results, both because unemployment represents waste of resources and because high labour taxes tend to generate too strong incentives for (voluntarily) devoting time to leisure (Bye, 2000). The aim of this paper is to measure welfare and employment effects for the Spanish economy within a consistent framework, by applying a CGE model that incorporates the specific labour market characteristics of Spain. Such a combined approach is rare in the literature, and though integrated models of the EU as an entity have been applied (Carraro et al., 1996), the outstanding Spanish case, in detail, is still not addressed.

The scope for employment dividends, as well as welfare dividends, depends on the features of the labour markets, in particular their flexibility and wage formation. In many respects Spain's labour market institutions and unemployment problems are special. Dolado et al. (1998) stress the relatively high weight of unskilled unemployment in Spain compared to the EU average. Blanchard *et al*. (1995) identify the main reasons for the high unemployment to be the collective structure of wage bargaining combined with high employment protection for part of the labour force. Bover et al. (2000) also emphasise the role of generous unemployment benefits. In addition, there are large regional unemployment differences, due to a relatively low mobility of labour across regions. Another common argument is that large wedges between take-home pay and the cost of labour hamper employment. Payroll taxes are high in Spain (see, e.g., Bajo and Gómez-Plana, 1999), and lowering the wedges may reduce labour costs and encourage Spanish employment.

We represent the mechanisms of the Spanish labour market as matching processes and distinguish between skilled and unskilled workers, due to important differences in supply and demand, and thus in policy responses. The labour supply is endogenous, and we separate between employment effects from adjusted supply behaviour and from changes in the number of unemployed, respectively.

Bovenberg and van der Ploeg (1998) show that the potential for a double dividend would depend on various elements that can be defined in a matching function. Matching processes and mismatch seem to describe the Spanish labour markets well, as there is a highly intensive matching process. In 1996, there were more than 8.5 million hires out of a labour force of 16 millions (Castillo et al., 1998). This is mainly due to a high number of workers hired under fixed-term contracts (31.7% in 2001 while the EU average was 13.4%). These contracts are most prominent among less educated (Toharia, 1996). Low geographical mobility also causes a significant mismatch problem. Matching models can, as well, represent the frictions caused by presence of labour unions. Bosello and Carraro (2001) model the labour market based on assumptions on union bargaining power. This is a good approach for some European countries, but as the Spanish labour market is characterised by a gap between a very low unionisation rate and the bargaining coverage rate (Blau and Kahn, 1999, p. 1418), the union bargaining power approach is less suitable for Spain. We follow the matching specification in Balistreri (2002), which is a new way of introducing equilibrium unemployment in CGE models. Our model also takes into account that market power is prevalent in several Spanish industries, not least in the emission-intensive productions of energy and of transportation (Huergo, 1998). We quantify the impact of imperfect competition and increasing returns to scale on the results.

Our results are encouraging with respect to the social costs of restricting CO_2 emissions. The aggregate unemployment effects of pricing Spanish CO_2 emissions are minor, as only a small fraction of the labour force is employed in the most affected industries. Moreover, if sales revenue is targeted to cut labour taxation, unemployment falls. This is especially true if direct, rather than indirect, labour taxation is reduced. The best option is to reduce payroll taxes on skilled employment. This reform is the most successful both in increasing demand and in dampening the supply response to rising wages. However, from a distributional point of view it is less attractive, as the unemployment rate for the unskilled increase. All the recycling schemes generate dividends in terms of welfare, but none offset the abatement costs entirely.

2. Method

2.1 The design of the analysis

We perform our analysis based on simulations on a large-scale CGE model for the Spanish economy. Employment dividends are defined in terms of unemployment rate reductions rather than employment formation. Changes in employment, which are also reported, partly arise from voluntary labour supply adjustments, partly from involuntary unemployment changes. Even though both mechanisms have relevance to the welfare effects we analyse, we attach particular interest to the unemployment phenomenon in itself, due to its distributional and socio-psychological aspects. The employment and welfare dividends are addressed by simulating reductions in the number of emission permits from the benchmark level. We present the results of 25 percent reductions.[1] The benchmark price for permits is zero, but when permits become scarce, firms begin to bid for them and the price increases. This can be interpreted as an open auction of permits with a uniform price (or equivalently, carbon taxation).

We simulate five revenue-recycling alternatives:

Case A: Lumpsum transfers to households,

Case B: Reduced payroll tax rates for all labour, irrespective of skill levels,

Case C: Reduced indirect taxes, exemplified by the VAT rates.

Case D: Reduced payroll taxes exclusively for unskilled labour.

Case E: Reduced payroll taxes exclusively for the skilled.

As lumpsum recycling is, by definition, undistortionary, the simulation in Case A is useful for cultivating the pure effects of introducing a price on emissions (*the pure abatement effects*). Comparing the other, more policy-relevant, recycling cases with Case A enables us to isolate the contributions of the recycling schemes (*the recycling effects*). Comparing the different revenue recycling schemes in Cases B, C, D and E will illuminate how recycling should be directed in order to minimise unemployment and reveal to what extent the reforms are associated with tradeoffs between welfare and employment dividends.

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[1] Smaller, as well as larger, reductions show the same qualitative results, and all variables react smoothly to the variations in emission restrictions.

We close the analysis by investigating the sensitivity of our results to model characteristics and parameter assumptions. First, we identify how the assumptions of imperfect competition and increasing returns to scale matter by comparing the results with corresponding results from a constant returns to scale model with perfect competition. While many CGE models used in the double dividend literature assume constant returns to scale, much empirical work casts doubt on this assumption. Second, we test the sensitivity of our results to different estimates of the externality parameters in the labour market matching functions, which should be considered uncertain. We compare the outcome of using deviating estimates from two Spanish studies, Burda and Wyplosz (1994) and Castillo *et al.* (1998). Finally, we perform a simple test of the impact of our imperfect labour market assumptions.

In order to give a better intuition and be able to decompose the results of the large-scale model, a stylised, reduced form of the model is also presented. The miniature model reflects the major mechanisms in the large model and makes them more transparent. The main characteristics of the numerical model are outlined in section 2.2. For details see Appendices 1, 2, and 3. Section 2.3 derives the miniature model and visualises it in a two-equation diagram.

2.2 The numerical model

The numerical model is a static CGE model, where the main refinements are made in order to capture the relevant welfare and employment outcomes for the Spanish economy of changes in carbon policy and labour taxation. In particular, the model incorporates important features of the Spanish imperfect labour markets, a comprehensive description of the existing tax structure, imperfect competition and other distortionary wedges within the Spanish economy, as well as disaggregate structures of household utility, production and factor use, in order to represent relevant substitution possibilities decisive to the policy responses. The model also computes CO_2 emissions on a detailed level both from firms and households.

Spain is modelled as a small, open economy. Goods are differentiated by origin (domestic and foreign), according to the Armington assumption. The balances of trade and financial cross-border flows are fixed. This avoids continuous net capital flows in or out of the country. All agents, except the public sector, have optimising behaviour. The aim of the public sector is to balance revenues according to an exogenous restriction, which we keep constant, i.e. all policy changes are revenue neutral. A macroeconomic restriction fixes public investment and deficit (or surplus), implying that public savings are, as well, fixed. Revenues from market sales of CO_2 permits are included in the public income.

Primary factor endowments are given and mobile across industries, and factor markets clear by adjustments in factor prices. However, the fact that labour markets far from clear in the Spanish economy is taken care of by allowing for equilibrium unemployment (see below). In macro, savings are fixed, and investments and savings balance.

In order to model that market power is prevalent in several Spanish industries, the degree of competition is allowed to vary among industries, according to the degree of firm concentration: High concentration (high Herfindahl indexes) corresponds to less competitive sectors. The higher concentration, the higher mark-ups. This pricing rule is based on profit maximisation, price-elastic demand functions and Cournot competition, i.e., firms take the supply of the others as given when deciding their own production. All firms within an industry are identical. Technologies exhibit increasing returns to scale due to the existence of some fixed labour and capital costs. There is free entry and exit of firms in each sector, so that in equilibrium price equals average costs, inclusive of the fixed costs.

Defining the mark-up as the price-cost margin (P-MC)/P = MARKUP, and using that, in equilibrium, price is equal to average cost (P = AC), we find that MC/(1-MARKUP) = AC. This mark-up is specified as follows:

(1) $$MARKUP_i = \frac{\Omega_i}{E_i \kappa_i^d}\text{, } i=1,\ldots,16$$

This is the Lerner index for sector *i*, and depends on three variables: The conjectural variations parameter Ω_i (in our case: $\Omega_i = 1$[2]), the perceived elasticity of demand faced by sector *i* (κ_i^d), and the share of a typical firm in sector *i*'s output, that is equal to the inverse of the number of firms in each sector ($1/E_i$). This share can be proxied in the benchmark by the Herfindahl index (see Appendix 3), under the assumption of symmetric firms in each sector.

The production sector is specified by 16 industries (see Table 1). Firms maximise profits subject to a production technology characterised by a detailed, nested structure (see Figure 1). CO_2 emissions from firms originate from the use of fossil energy as input factors. In our static framework, investments show their influence on the economy as a component of final demand. Private households are assumed

[2] Usually conjectural variation is defined so that it is equal to zero with Cournot competition. However, here the conjectural variation parameter is normalized to unity.

to share homothetic and identical preferences. Hence, they can be represented by a single, representative household. The household maximises a nested welfare function (see Figure 2) by choosing savings[3], leisure, and consumption of goods (including energy). The household generates CO_2 emissions when it consumes coal, oil and gas. However, the quality of the environment is not specified in the welfare function. Endowments of capital, as well as skilled and unskilled labour, are fixed. The labour supply is elastic up to these fixed maximum amounts. This feature of the model enables us to analyse to what extent adjustments of labour supply explain changes in the unemployment rates.

Based on Balistreri (2002), we assume a case of equilibrium unemployment, inspired by a matching specification and the theory of external economies (see, e.g., Markusen, 1990). A matching function gives the number of jobs formed as a function of the number of workers looking for a job (unemployed), and the number of firms looking for workers (vacancies); see Petrongolo and Pissarides (2001) for a recent survey of the matching function in macroeconomics. With this approach, frictions due to lack of information, immobility, search costs, heterogeneities across workers and jobs, etc. can explain the existence of unemployment or vacancies. Following Balistreri, we model frictions by assuming that workers have to spend some resources in finding a job, so the search process is costly. We assume that all search costs are borne by the workers. This means that real received wages, net of taxes, W^j, include a premium ($\frac{1}{H^j} > 1$) on reservation wages (W^j_0) that represents search costs:

(2) $$W^j = W_0^j \frac{1}{H^j}, j = s, us$$, where s = skilled, us = unskilled workers.

Another feature of Balistreri's approach is externalities. The unemployed views the search cost as given. However, the risk of not being matched, represented by the search cost, is affected by the behaviour of all other agents. If, for instance, the labour market expands, labour demand increases and the cost of participating in the market falls; it is easier to find a job. If the unemployment rate increases, vacancy congestion decreases and the matching process eases. We model this by assuming that the *H*-functions (inverse premium) has properties similar to matching functions:

[3] Given our static approach, we consider a unitary elasticity of substitution between consumption and savings (see Howe, 1975). Savings can be interpreted as the purchase of bonds for future consumption.

$$H^j = \left(1-\overline{U^j}\right)\left(\frac{LD^j}{\overline{LD}^j}\right)^{\eta_0}\left(\frac{U^j}{\overline{\overline{U^j}}}\right)^{\eta_1}, j = s, us, \tag{3}$$

where a bar denotes a benchmark value for the referred variable, *LD* is aggregate demand for labour and *U* is the unemployment rate. *H* is increasing in *LD* and *U*, i.e., the search cost is decreasing in the same variables. Following Balistreri (2002), vacancies are, for simplicity, absent in this model, and labour demand is used as a proxy. This means that total employment follows the labour demand curve. η_0 is the elasticity with respect to vacancies. It measures the positive externality caused by firms on searching workers, here represented by a lower search cost. η_1 is the elasticity with respect to unemployment and measures the positive externality from workers to firms.

The model is solved through Rutherford's (1999) method, which treats general equilibrium models as mixed complementarity problems following Mathiesen (1985), and it is implemented with GAMS/MPSGE. It has been calibrated using the Spanish Social Accounting Matrix for 1990, MCS-90, developed in Uriel *et al*. (1997) and Gómez-Plana (2001), as the reference equilibrium. Elasticities are taken from available empirical evidence. See Appendix 3 for more information on calibration and data.

2.3. A stylised, reduced-form miniature model

As a tool for the analysis of the results stemming from the full, numerical model simulations in the next section, we use a reduced-form, less specified representation of the model. Large-scale models may often appear as black boxes when explaining results. The miniature model reflects the major mechanisms in the large model and makes them more transparent. It suppresses many details of the larger model, for instance, there is only one labour market and one product market. It also suppresses the search cost function..[4] In eqs. (4) to (7) the equilibrium of the stylised model is expressed by only four equations, the labour market equilibrium, the trade balance, the indirect welfare function and the capital market equilibrium. All other equations and equilibrium conditions, such as the product market equilibrium and the revenue neutrality constraint of the public budget, are implicitly defined:[5]

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[4] Including it would provide a separate determination of the two components of the wage rate, reservation wage and search costs (see eq. 2), and clarify the more complicated relationship between the wage and unemployment determination. But signs would not change. See also footnote 11.

[5] A detailed presentation of the stylised model and its reduction into four equations is available from the authors on request. See also Fæhn and Grünfeld (1999) for a more extensive presentation of a similar procedure, inspired by Holmøy (1992).

(4) $L^S(W, R, U; \varepsilon)(1-U)=L^{D*}\{W, R, \varepsilon, X[W, R, \varepsilon, Q_{cg}(W, R, U; \varepsilon)]\}= L^D(W, R, U; \varepsilon)$

(5) $\overline{D} =D^*\{W, R, \varepsilon, Q_{cg}(W, R, U; \varepsilon)\}= D(W, R, U; \varepsilon)$

(6) $WF = WF^*\{Q_{cg}(W, R, U; \varepsilon), L^S(W, R, U; \varepsilon)\} =WF(W, R, U; \varepsilon)$

(7) $\overline{K} =K^{D*}\{W, R, \varepsilon, X[W, R, \varepsilon, Q_{cg}(W, R, U; \varepsilon)]\}= K^D(W, R, U; \varepsilon)$

Notation[6]:

L^S=	labour supply
L^D=	labour demand
W=	the labour rent/the wage rate
R=	the capital rent/the user cost of capital
U=	the unemployment rate
ε=	vector of all exogenous variables
X=	domestic output
Q_{cg} =	demand for aggregate consumption of goods
$\overline{D}$ =	fixed trade balance
WF =	welfare
$\overline{K}$ =	fixed total capital
K^D=	capital demand

Eq. (4) represents the unemployment-adjusted labour market equilibrium, corresponding to eqs. (A6) and (A7) of the numerical model.[7] It distinguishes between five effects of changes in the endogenous W, R and, U, and ε, which includes exogenous reform components like tax rates and emission restrictions (determining the quota price; see eq. (A31)):

(i) Substitution effects: The first appearance of *W*, *R* and *ε* in the L^{D*}- function represents changes in relative labour to capital demand of altering wages, capital rents and exogenous variables.

[6] Note that a star after a symbol represents a different functional form, e.g. WF*(.) and WF(.) are two different functional forms expressing the variable WF.

[7] All equations of the full model are listed in Appendix 2. See also Appendix 1 for the notation of the model.

(ii) Competitiveness effects: W, R and ε also affect labour demand through altering production costs and thus the international competitiveness of Spanish firms. This alters output (X) and subsequent input of labour.

(iii) Home market effects: X also depends on the domestic demand for the final good, Q_{cg}, which is a determined by prices and income. These are functions of factor prices, the unemployment rate that first of all affects the income of the aggregate household, as well as exogenous variables.

(iv) Labour supply effects: Left hand side of eq. (4) shows that through the household's decisions, labour supply is dependent on the same price and income determinants as the demand for final goods described above.

(v) Unemployment wedge effect: The term *(1-U)* captures that the unemployment rate influences the labour market equilibrium directly.

The net current account is restricted through fixing the trade balance to $\overline{D}$, as in eq. (5). This corresponds to eq. (A.37) in Appendix 2. Eq. (5) distinguishes between two channels, through which the endogenous and exogenous variables influence the current account:

*(vi) Competitiveness effect*s: The current account restriction responds to cost changes that alter the competitiveness of Spanish firms, and thus imports and exports.

(vii) Home market effects: Effects of changes in the domestic final consumption, Q_{cg} comes through import leakages.

Eq. (6) defines welfare as a function of the utility of demanded consumption goods, Q_{cg}, including savings, and demanded leisure, which is implicitly a function of labour supply, L^S (see eqs. (A17) and (A20)). The determinations of Q_{cg} and L^S are explained above.

Equilibrium capital demand, K^D, is restricted to the given capital stock, $\overline{K}$. As eq. (A5) of the numerical model, eq. (7) ensures this. Analogous to the labour demand, capital demand is influenced by *Substitution effects*, *Competitiveness effects* and *Home market effects*.

The four equations solve for the four endogenous variables WF, W, R and U. We can reduce the model further, by solving eq. (6) for W, eq. (7) for R, and then inserting the latter into the former. For a given ε, W and R are determined by WF and U:

(6'): $W=W(WF, U; \varepsilon)$

(7'): $R=R^{*}(W, U; \varepsilon)= R(WF, U; \varepsilon)$

Using eqs. (6') and (7') leaves us with the labour market equilibrium and the current account expressed in eqs. (4) and (5) as functions of only two endogenous variables, *WF* and *U*, which again implicitly determine all other variables in the model. The benefit of a two-equation model is that it can be easily visualised, as in Figure 3. It is important to notice and keep in mind in the analyses in Section 3, that through eqs. (6') and (7') *all* the effects of endogenous changes in *WF* work through the factor prices in eqs. (4) and (5). For given *U*, increased *WF* must involve factor price increases (from now on represented by the nominal wage rate, *W)*.[8] Analogously, many of the effects of *U*-changes also take place via changing factor prices. However, contrary to *WF*, *U* also influences eqs. (4) and (5) directly. It has an independent impact on the *(iii) Home market effects* in eqs. (4) and (5), and *(iv) Labour supply effects* in eq. (4), and finally has the *(v) unemployment wedge effect* in eq. (4). In spite of the various effects via the factor prices, we have chosen *WF* and *U* as the remaining endogenous variables in the analysis, simply because they directly give us the resulting welfare and employment dividends that our shift analyses of CO_2 policy reforms and revenue recycling schemes focus on.

In Figure 3, the LL^0-locus and the DD^0-locus are defined as the combinations of *WF* and *U* that for the exogenous benchmark values, ε^0, fulfil eqs. (4) and (5), respectively. Where both conditions are fulfilled we find the equilibrium solution of the model in the benchmark case, i.e. in the intersection coordinate (WF^0, U^0). Both the slopes of the loci, as well as shift effects of exogenous reforms will depend on the relative strengths within the Spanish economy of the mechanisms *i)* to *vii)* described above.

The slopes express the necessary change in *U* for different, exogenous shifts in *WF*, keeping, respectively, the labour market equilibrium and the trade balance intact. They are identified by means of simulations of the numerical model[9]. To start with the LL locus, its positive slope implies that a

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[8] Simulations on the numerical model show that the strongest impact of *WF* on factor prices comes through the indirect utility expressed by eq. (6): A rise in *WF* will have to involve real income improvements, and for given *U*, factor price increases must take place. The simulations show that a partial rise in *WF* causes wages to increase relatively more than capital rents, and nominal wages more than the prices of consumption goods so that the real wages increase. In the following we suppress the effects on capital rents, as they only work to dampen the conclusions from a discussion focusing on nominal (and real) wages.

[9] For simplicity, in these simulations the labour market has been merged into one in the numerical model, in order to operate with only one aggregate unemployment rate, wage rate etc.

distortion in the labour market equilibrium resulting from a given relative *increase* in *WF* will have to be neutralised by a simultaneous *increase* in *U*. The explanation is that increased *WF*, in isolation, creates a labour demand deficit in the Spanish economy, while an increase in *U* creates a surplus, which rebalances the labour market. In other words, moving rightwards and/or downwards from a point on the LL locus produces a labour demand deficit, while points to the left and/or above the locus represent situations with labour demand surpluses.

As already emphasised, the effects of a partial increase of *WF* work through factor price increases, represented by the nominal wage rate, *W*. The labour demand shortage resulting from a partial *WF* increase is due to a relatively stronger joint influence of the wage increase via the positive *(i) Substitution effects*, *(ii) Competitiveness effects* and *(iv) Labour supply effects* than via the negative *(iii) Home market effects*. This reflects characteristics of the Spanish economy: While *(iv)* contributes to increase net labour supply through a higher price of leisure, the major explanations are the labour demand reductions resulting from *(i)* and *(ii)*. Though the Armington elasticities are not very high - cf. Table A3 - the fact that internationally competing industries are relatively labour intensive (particularly metal production contributes to this) cause significant *(ii) Competitiveness effects* of increased *WF*, and thus wages. The *(i) Substitution effects* are less easy to track, but the substitution elasticities listed in Table A3 indicate rather responsive labour-to-capital rates at the firm level. A real wage increase induces both substitution and income effects in favour of increased consumption and subsequent, counteracting *(iii) Home market effect*s on labour demand. However, consumer goods are relatively capital intensive - and becomes even more so when prices of labour intensive goods increase in relativel terms, rendering the *Home market effects* on labour demand relatively weak. First of all consumption of trade services, other manufacturers and renting contribute to the high capital intensity. The responding *rise* in *U* in order to neutralise this excess labour supply is due to a dominating *(v) Unemployment wedge effect* that causes a direct reduction of excess supply through a drop in the term *(1-U)* in eq.(4). Other mentioned effects of *U* work in the other direction.[10]

As illustrated in Figure 3, also the slope of the DD-locus is positive, implying that *WF* and *U* work in opposite directions on the trade balance. Partially increasing *WF* rises nominal and real wages and

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[10] Increased *U* for given *WF*, would have to involve increased wages via the indirect welfare function in (6) that contribute to reinforce the excess supply of labour through the same mechanisms *(i)* to *(iv)* discussed above. Also the independent impacts of *U* in *(iii)* and *(iv)* increase net labour supply. Increased *U* reduces household income and reduces labour demand through the *(iii) Home market effects*, while simultaneously increasing labour supply by reducing leisure demand. In addition, another effect of *U*, which is suppressed in the stylised model exposition, also contributes to reduce excess supply somewhat: Increased *U* reduces the search cost component of the wage rate directly (see eqs. (A38) and (A39)) due to the externalities of the matching process (see eqs. (A40) and (A41)). This effect also contributes to the simulated positive slope of the LL-locus in Figure 3, but is weak.

affects the trade balance adversely both through *(vi) Competitiveness effects* and *(vii) Home market effects (vii)*. An increase in *U* will help restoring the trade balance restriction. The dominant effect of increased *U* in the Spanish economy is to decrease import leakage through negative *Home market effects (vii)*. Consumer goods with high (input-output-adjusted) import shares are first of all metals and other manufacturers. The slope of the DD-locus implies that being off and *above* the DD-locus represents situations with smaller deficits than required by the current account restriction, while at points *below* the curve, deficits are too large.

3. Unemployment and welfare effects of carbon permits

3.1 Case A: Lumpsum recycling

In order to wind up the main mechanisms producing the results in Case A, we exploit the stylised model presented in Section 2.3. In Figure 3, the equilibrium solution of Case A is marked in the point (WF^A, U^A), which represents the intersection between the loci LL^A and DD^A. The respective shifts from the LL^0 and DD^0-loci reflect that the ε-vector has changed due to the exogenous restriction on CO_2 emissions. The direct effect is to impose a price wedge between the consumer and producer price of fossil fuels. Figure 3 shows that, relative to the benchmark, both loci shift upwards in the relevant area. As explained in Section 2.3, these points are characterised by *WF*s and *Us* that, for given $\varepsilon = \varepsilon_0$, would create a labour demand surplus. In other words, the partial effect of moving from ε_0 to ε_A is to create a labour demand *deficit* that has to be neutralised. This deficit is the net result of effects through the four main channels for ε-impacts already described in Section 2.3 - confer eq. (4). Lower demand follows from the *(ii) Competitiveness effects* and *(iii) Home market effects*. The former reflect that internalising the costs of emitting deteriorates the competitiveness of domestic firms. The latter are consequences of lowered real wages when prices rise. This discourages consumers' demand for goods and, thus, firms' demand for labour. Neither the internationally exposed goods, nor the consumer goods have very high *direct* fossil fuel intensities, but as prices of inputs, first of all electricity and transport services, increase, the CO_2 permit pricing significantly raises the costs within exposed industries and final goods industries. *Labour supply effects (iv)* and *Substitution effects(i)* contribute to weaken, but not offsetting, the labour demand deficit; the first through reducing labour supply, the latter through increasing labour demand. Labour supply falls in the wake of higher consumer prices of fossil fuels, as well as goods produced by fossil fuels. *Substitution effects* contribute to increase labour demand, as the capital-intensive industries tend to face the highest CO_2 permit costs. This causes a substitution of relatively labour intensive production for capital intensive. However, as share of total capital use, the fossil fuel intensive industries are not very important, so this effect is small.

Simultaneously, the DD-locus shifts from DD^0 to DD^A. As the new (*WF*,*U*)-points lie *above* the DD^0-locus, we know that their adjustments, in isolation, cause a current account improvement from the benchmark (see Section 2.3). For this to balance current account, the CO_2-policy reform must have caused a corresponding current account reduction. The explanation is that the lumpsum reform affects the current account through two main channels (see the ε's in eq. (5)): Increased emission prices imply a competitiveness loss that deteriorates the trade balance. This negative *(vi) Competitiveness effect* turns out to dominate the positive *(vii) Home market effect* caused by reduced import leakage when domestic income decreases.

The new intersection point reflects that introducing a CO_2 permit reform will not notably affect aggregate *U*. This challenges the frequently expressed concern for accentuated Spanish unemployment in the wake of climate policy action. It mirrors that the fossil fuel intensive part of the Spanish economy is relatively capital intensive. Thus, from the industries producing or consuming CO_2-intensive products, most notably production of *Electricity*, *Coal, Gas* and *Water Supply*, mainly capital is released. But along with it, relatively small amounts of labour, primarily unskilled also leaves these industries. The capital is mainly absorbed through substitution of primary factors for fossil fuels in the contracting *Chemicals*, *Other Manufacturing*[11] and *Road Transport* industries, and through a significant expansion of *Agriculture*. The released labour is mainly re-employed in these same industries. In fact, total employment increases slightly (see Table 2a), reflecting that the negative shift in the labour demand caused by *Competitiveness effects* and *Home market effects* of the CO_2 permit prices, is more than offset in the new equilibrium by relative wage reductions that stimulate demand. However, as labour supply simultaneously rises, the unemployment rate remains unaltered. The disaggregated results reveal that the rise in employment only benefit the unskilled, while employment of skilled labour falls marginally.

The simultaneous welfare loss following the factor price reductions amounts to 0.93 percent. This pure abatement cost lies in the lower range of those from other European studies (see IPCC, 2001, Bye et al., 2002, Bosquet, 2000). One explanation is differences in the employment results: European studies usually find that employment drops. This tends to intensify the abatement costs due to significant tax interaction effects with existing labour taxes.

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[11] The *Other Manufacturing industry* includes the unskilled intensive manufacture of textiles and wood products.

3.2 Case B: Recycling through reduced payroll tax rates on all labour

Adding recycling effects of reduced payroll taxes on all labour to the pure abatement effects in Case A corresponds to the more policy-relevant Case B, which is also illustrated in Figure 3. The move from (WF^A, U^A) to (WF^B, U^B) illustrates that the isolated revenue recycling effects of this scheme are to strengthen the employment dividend and to partly offset the welfare loss. In terms of the loci, the payroll tax reductions change ε and cause the loci to shift to LL^B and DD^B, both lying *below* the respective locis of Case A. Thus, *cet. par.*, the *WF* and *U* movements would cause a demand deficit in the labour market along with an increased current account deficit. Accordingly, as we are in a new equilibrium, the recycling scheme has caused the opposite: A labour demand surplus and a current account improvement. These are results of counteracting effects that can be tracked by using eqs. (4) and (5), as above. In the labour market, *(iv) Labour supply effects* of the change in ε contribute to decrease net demand, as lower payroll tax rates reduces market prices, i.e. raise real wages of consumers. However, this effect is inferior to the other three effects *(i) -(iii)*, which all increase labour demand and cause excess demand: *(i) Substitution effects* through lowered labour prices, *(ii) Competitiveness effects* through the subsequent competitiveness improvements, and *(iii) Home market effects* through higher real income and demand. The current account improvement caused by lower labour costs is explained by the favourable *(vi) Competitiveness effects*. *(vii) Home market effects* counteract somewhat through higher import leakage, but turns out to be inferior.

Table 2b shows that the unemployment rate for skilled and unskilled labour falls by 0.33 and 0.20 percent, respectively, due to the revenue-recycling scheme. This is due to the joint positive impact of the *Substitution effects, Competitiveness effects* and *Home market effects* on labour demand compared to the lumpsum case. The effects are relatively small, as also found in the surveys of Mors (1995), Majocchi (1996) and Bosquet (2000).

The recycling effects increase welfare by 0.48 percent. A main reason is that labour taxation leads to sub-optimally low levels of labour supply and employment. Cutting the payroll tax rates counteracts this distortion. Comparing Case B with Case A reveals that the welfare gain of the revenue recycling almost bisects the abatement cost of the CO_2 permit system. Such weak double (welfare) dividends of labour tax recycling are found in most of the European studies referred to above.

3.3 Case C: Recycling through reduced VAT rates

The case of recycling revenue through VAT reductions is also illustrated in Figure 3. As for Case B, both loci are shifted downwards compared to the lumpsum case, indicating that the recycling effects generate a labour demand surplus, as well as a current account improvement. However, none of the shifts are as strong as in the case of payroll recycling. In the labour market, *Substitution effects* are of much less significance, since VAT also implicitly taxes capital. *Home market effects* and *Competitiveness effects* still stimulate labour demand and outperform the positive *Labour supply effects* of lower consumer prices. The favourable *Competitiveness effects* also explain the current account improvement.

To counteract the imbalances, factor prices increase in the new equilibrium. The result in terms of *WF* and *U* is marked in the point (WF^C, U^C). It reflects that a very weak employment dividend is obtained from the VAT recycling, as opposed to the payroll recycling. The employment stimuli caused by the *Competitiveness effects* and *Home market* effect, as well as the positive *Labour supply effects* are counteracted, and almost offset by factor price increases; see Table 2b. These results indicate that unemployment should rather be combated through direct reductions in labour costs.

As reported in Table 2b, the weak double welfare dividend is positive, as also found for other countries (see the above mentioned surveys). However, while the literature tends to find that VAT recycling is less welfare generating than payroll tax recycling, we find a slightly better welfare result in case of VAT recycling. Our study supports the general finding that reducing the VAT rates contributes less to cutting the effective labour taxation. This contributes to a relatively weaker welfare gain in our study as well as in most others, because consumption increases less relative to leisure, and employment of labour increases less (relative to capital). However, other welfare contributions more than outweigh this disadvantage of VAT recycling in our study. First, compared to the payroll reductions, the VAT reductions leave the consumer prices less distorted; in particular, the difference between energy prices and other consumer prices is smaller. Second, the initial VAT taxation on domestic output tends to outperform the joint VAT and tariff wedge on imports, implying a distortion of resource allocation in disfavour of home-maid products. Thus, the relative price reduction of domestic goods resulting from the VAT recycling, results in a welfare-improving increase of Spanish market shares at home.

3.4 Case D: Recycling through reduced payroll tax rates on unskilled labour

Distributional reasons could call for a revenue recycling policy designed to stimulate unskilled labour, in particular, due to the fact that the unemployment rates are twice as high for unskilled as for skilled labour. This could also be a case for reaping higher employment dividends than in the case of non-discriminatory payroll recycling. If the fossil fuel intensive industries use unskilled labour relatively more intensively than skilled labour, a relative subsidy to employment of unskilled workers could help to absorb the released labour more efficiently. Also, the relative effect on wage costs of lowering payroll taxes will be higher for unskilled labour than for skilled, due to the low wage rates of unskilled workers, implying that the change in the wage costs will be larger.

However, our results contradict the hypothesis that employment dividends increase when revenue recycling is targeted to the low skilled. We find a much smaller employment dividend in macro in this recycling regime than in the non-discriminatory recycling scheme in Case B - see Table 2b. *U* falls by only 0.08 percent as opposed to a reduction of 0.24 percent in Case B, and the increase in aggregate employment is also lower. Behind these aggregate results lie significant differences between the two skill groups. While the non-discriminatory recycling in Case B gained both groups, exclusively recycling revenue through the costs of unskilled labour reduces the unemployment rate for this group, only. This is offset by a rise in the unemployment rate of skilled labour. The recycling effects are qualitatively illustrated in the market diagrams for unskilled and skilled labour in Figure 4a and 4b. In the unskilled market, the isolated effect of reducing payroll taxes is to generate positive *Labour supply effects* through price reductions, as well as positive *Competitiveness effects*, *Home market effects* and *Substitution effects* on demand. In particular, the *Substitution effects* contribute to a significantly higher demand for unskilled labour than in Case B. Other cost changes, primarily through factor price increases, modify the shifts. The subsequent excess labour demand is neutralised by an increased unskilled wage rate and a reduced unemployment rate, and in the new equilibrium, the revenue recycling scheme has contributed to increase unskilled labour wages by as much as 4.76 percent, while the unemployment rate has fallen by 0.42 percent, reflecting a labour demand increase of 1.10 percent and a somewhat weaker labour supply increase of 1.00 percent.

In the market for skilled labour, the shifts are weaker, in particular the demand shift, due to the significant counteracting *Substitution effects* away from skilled labour caused by the cost reductions of unskilled labour. Before any adjustments in the wage rate and the unemployment rate of the skilled, the labour market unbalance is less serious than in the market for unskilled labour. The equilibrium unemployment rate and wage rate for the skilled part of the labour force increase by 0.19 and 0.65 percent, respectively. The increased unemployment rate mirrors that the *Substitution effects* are strong and contributes to leave skilled labour employment 0.32 percent lower than in the lumpsum case.

The targeted recycling to unskilled labour generates a weak welfare dividend of about the same magnitude as does the recycling through *all* payroll taxes in Case B. This reflects the strong significance of employment effects in generating welfare: Aggregate employment rises to about the same extent in the non-discriminatory and discriminatory recycling schemes, and this contributes to increase welfare both directly, as employment is sub-optimally low initially, and through decreasing the number of unemployed.

Compared to Case B, the employment of unskilled more than doubles. But at the same time the employment of skilled labour decreases sharply and leave aggregate employment somewhat lower than in Case B. The downward pressure on skilled labour demand is mainly explained by three mechanisms: First a general substitution of unskilled for skilled labour will take place in each firm, encouraging employment of unskilled at the expense of skilled. In addition, the relatively skilled-intensive part of the economy (mainly within the service sector) will reduce its ability to attract resources as their relative costs increase. This contributes to reduce skilled labour demand in macro.

The third effect comes through the interplay between capital and labour demand. The direct effect of subsidising the unskilled labour costs is to reduce relative prices between unskilled and capital much stronger than in Case B. In relatively unskilled-intensive *and* capital-intensive industries, not only a substitution between labour types, but also a substitution for capital, takes place. Thus in the expanding part of the economy, most prominently within trade and unskilled intensive manufacturing, capital demand decreases. The capital must be absorbed elsewhere, and through relative factor price adjustments, the contracting, skilled intensive part of the economy is stimulated to absorb capital. Subsequently, capital demand increases in spite of output reductions in the high-skilled service sector, implying that skilled labour is squeezed both by unskilled labour and by capital. As a result, aggregate production and employment falls relative to Case B, and this tends to take place in the relatively skilled-intensive part of the economy, primarily within the skilled service sector.

Our results counter the claims that targeting the revenue to the low skilled reduce employment more effectively. Like Bosello and Carraro (2001) we find that subsidising costs of both types of labour is better than targeting revenue merely to the unskilled. While their results are mainly explained by substitutability between the two labour types within the production processes, our findings for Spain also point to important effects from changes in the industrial structure, and from the substitution between capital and the two labour types both at the firm level and in macro through resource reallocations among industries. This leads naturally to the question addressed in the next section of whether targeting to skilled labour have more promising employment effects.

3.5 Case E: Recycling through reduced payroll tax rates on skilled labour

Qualitatively, the opposite story as for Case D applies to this case of recycling the revenue exclusively through *skilled* labour costs, and it can be illustrated simply by changing the labels of the Figures 4a and 4b. As in Case D, discriminating between labour groups generates strong substitution effects that explain most of the differences between the discriminatory and non-discriminatory cases, but here the opposite labour demand impulses with respect to skill groups occur. As reflected in Table 2b, wage rates for the skilled increase more than for the unskilled, and the unemployment rate falls for the skilled, while that of the unskilled increases. The most interesting observation from the analysis of Case E is the strong employment dividend obtained in macro. The overall unemployment rate drops by 0.44 percent, which implies that revenue recycling through skilled payroll tax rates turns out as the most recommendable scheme, and noticeably more effective than recycling though the wage costs of unskilled labour (Case D). Behind this result lie both a higher labour demand and a lower labour supply than in Case D.

The higher labour demand is partly explained by a stronger effect on demand for the subsidised skill type in Case E than in Case D, because the tax cut is more substantial when allocated to the relatively fewer skilled workers. In addition, higher labour demand is due to a stronger negative impact on the disfavoured skill type in Case D than in Case E. We have to revisit the role of the interlinkages between the demand for capital and the two labour types, in order to understand this. In both cases of discrimination, the less taxed skill type increases its intensity within firms, and industries using it relatively intensively increase their share of total production. However, the two recycling schemes differ in their effects on capital demand. Compared to the unskilled intensive industries, the skilled intensive industries are relatively less capital intensive and the substitution between capital and labour smaller. Thus, reducing the payroll tax on skilled labour and thereby increasing relative costs of capital in the skilled intensive part of the economy, releases less capital, *cet. par.*, than do a reduction of pay roll taxes of unskilled labour. Consequently, when recycling of the revenue is targeted to the use of skilled labour, absorbing the released capital within the unskilled-intensive, relatively capital intensive, contracting part of the economy is a smoother process than in Case D. Less labour is substituted by capital within these industries than within the contracting industries of Case D, subsequently the decrease of unskilled labour demand is smaller than that of skilled in the former case.

When recycling is targeted to skilled employment, first of all service industries where high skills are required, expand. However, compared to a targeting to unskilled, the contraction of the industries that use the relatively disfavoured skill type more intensively (in *this* case the unskilled) is less pronounced. All in all, production and employment increase compared to the two other, and more frequently analysed, cases of pay roll reductions.

Along with a higher aggregate labour demand, the higher employment dividend in Case E than in Case D is explained by a lower aggregate labour supply. This is related to a higher labour supply elasticity of unskilled workers than of skilled. The wage rate of the non-subsidised skill type - also in real terms - falls by about the same magnitude in the two cases. However, the subsequent discourage of the *skilled* labour in Case D is much smaller than that of the *unskilled* in Case E and contributes to a lower aggregate supply in the latter case. The fact that the wage rate of the skilled - also in real terms - increases considerably more in Case E, when skilled are favoured, than does the wage rate of the unskilled in Case D, modifies the difference in supply between the two cases, but all in all supply turns out lower when the relative subsidies are targeted to skilled employment rather than to unskilled.

To sum up, the result of a 0.04 percent points higher employment and 0.03 percent points lower supply in aggregate terms in Case E than in Case D explains the considerably lower *U*. It is, however, worth noticing the adverse effects the scheme in Case E has on the distribution of the unemployment burden. In all the other cases, the revenue recycling schemes work to reduce the unemployment rate of the unskilled. While subsidising unskilled labour produces the greatest difference between the skill groups in terms of unemployment, it goes in favour of the relatively low waged and low skilled. Subsidising skilled produce the opposite result.

The weak welfare dividend of the recycling scheme is of the same magnitude as in the other pay roll reducing schemes. It is worth stressing that the welfare measure does not consider distributional concerns.

3.6 Sensitivity tests

This section illustrates the sensitivity of the results to some key assumptions. First, we test the assumptions of imperfect competition and increasing returns to scale in production against the competitive, constant returns to scale case. Then, we test for alternative parameter values within the matching function in the labour market. The reported results in Table 3 apply to the sensitivity analyses of Case E, i.e. when CO_2 emissions are cut by 25 percent and revenue is recycled through pay roll taxes on skilled labour. This is the case where the strongest employment dividend was obtained. For the other recycling cases, the sensitivities to the tested assumptions do not deviate markedly.

Finally, we also comment on a comparison between simple toy models with different wage formation, to shed light on the consequences of using a matching model.

Sensitivity to the competition and returns to scale assumptions. We compare the results of assuming increasing returns to scale and imperfect competition with the more commonly assumed case of constant returns to scale and perfect competition. Table 3 shows that first of all the welfare dividend is sensitive to the assumptions on competition and returns to scale. In the case characterised by constant returns and perfect competition, the welfare costs of the reform are lower than in the non-competitive case. The main reason for this is that scaling down production is not associated with decreasing productivity and thus renders GDP and consumption somewhat higher. The effects on employment and the employment dividends turn out to be less significant, mainly due to offsetting effects on labour demand: The scales of production are less affected due to the absence of scale economies. This dampens changes in labour demand. On the other hand, the elasticity of labour demand increases. This is due to higher substitution effects when no costs are assumed as fixed, as well as an increase in the demand elasticities of goods. [12]

Testing the parameters in the matching function. In our test of the sensitivity of our results to different estimates concerning the externality parameters in the labour market matching functions (see section 2.2), we compare the results of Case E, based on values from Burda and Wyplosz (1994), with alternative estimates provided in Castillo *et al.* (1998) (*CJL*). The vacancy externalities from the two studies are approximately the same, 0.14 against 0.15. The main difference lies in their parameter estimates for the unemployment externalities. While *BW* estimate the elasticity to 0.12, Castillo *et al.* (1998) (*CJL*) find it to be as large as 0.85. The unemployment externality represents the externality from workers to firms, and stronger externality effects work through the search cost component of the wages. The tests show that the unemployment rates for the two skill types change in opposite directions. The change for skilled labour is most prevalent, as the matching is only affected to the extent that the unemployment rate deviates from the benchmark; see equation (3). The main driving force is a smaller increase in labour demand, as some of the substitution effects in favour of skilled labour is offset by the relative wage increase. As the results for unskilled labour have opposite signs, the effects in macro on unemployment, the employment dividend, as well as welfare, are weak.

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[12] See Fallon and Verry (1988, pages 83-90) for an analytical demonstration, or McConnell et al. (1999, chapter 5) for an economic intuition.

Testing different wage formation models. In order to easily calibrate the labour market to alternative models, we have chosen to perform a simpler analysis. We study a uniform tax cut on *all* labour within simple, aggregate toy models distinguishable by their wage formation mechanism. In the first, wages are fully flexible and eliminate all unemployment. In the second, our matching model is implemented, while the third is characterised by rigid wages. We find that decreasing the tax on labour reduces employment in all models. Compared to the flexible wage case, the employment increases more with the matching function, as unemployment and search costs fall. However, compared to a model with full wage rigidity, employment increases less. The reason is that the wage is adjusting in the case of matching, even if there are frictions in the labour market.[13]

4. Conclusions

This paper addresses the special challenges of Spain in meeting the international commitments on greenhouse gas emissions, while at the same time attend to its severe unemployment problems. Within a CGE framework, we model unemployment as a result of the matching process in the labour market, which seems to yield a good description of the Spanish labour market. This allows for studying welfare and employment dividends of carbon policies in relation, and also for taking into consideration the effects on labour supply. The endogeneity of labour supply has lead us to define employment dividends in terms of unemployment rates instead of employment, to sort out the effects on voluntary choices of leisure. Our qualitative findings do, however, not hinge on this change of definition. A special contribution of our work is to account for the substantial differences between the markets for unskilled and skilled labour markets in Spain, which enables us to supplement previous studies with assessments of policy alternatives directed to one of the labour market segments, only.

We find, in line with most other studies, that a carbon permit market in Spain, combined with revenue recycling through payroll tax reductions, increases employment, and leads to unemployment rate reductions. Our results are relatively optimistic, as adverse unemployment effects are avoided also in case of lumpsum recycling, i.e., when no payroll tax reductions are accounted for. This reflects first of all that carbon intensive sectors represent a low share of employment, especially of skilled employment, so that the economy is able to absorb the workers through expansion in other, relatively labour intensive industries.

[13] An appendix with more detailed results is available upon request from the authors.

The revenue recycling schemes have different potentials for reducing unemployment rates. As Bosello and Carraro (2001) find for Europe, pay roll tax reductions seem to yield smallest employment dividends when they are targeted to *unskilled* employment, only. However, a case not analysed by Bosello and Carraro (2001) seems to be the most promising, namely reducing payroll taxes exclusively for the *skilled* workers. When the supply effects are taken into account and unemployment rates calculated, the employment dividends appear to be quite sensitive to the recycling scheme: While using the revenue to lower payroll taxes on unskilled employment reduces the aggregate unemployment rate by only 0.08 percent, recycling through skilled payroll taxes reduces the rate by 0.44 percent. Recycling the revenue to both groups yields an employment dividend in between (-0.24 percent). The stronger employment dividend from recycling through costs of skilled labour is partly the result of a stronger stimulation of labour demand. The cut in costs of the subsidised labour type is stronger, as skilled labour constitutes a smaller group. But its interplay with capital is also important: Skilled labour tends to work in the least capital intensive part of the economy, implying that increased demand for skilled labour causes a modest substitution for capital and a subsequent modest need for absorbing capital by crowding out unskilled labour in other parts of the economy. Further, the supply response to rising wages is weaker than in the other revenue recycling alternatives, as the labour supply elasticity of the skilled workers are higher than that of the unskilled.

This result leaves a dilemma to policy makers due to its distributional implications: In spite of its stronger aggregate employment dividend, the recycling scheme will deepen the gap between the two skill groups in terms of unemployment rates. The entire employment dividend will come to the relatively advantageous and prosperous group of skilled, while the unemployment problem of unskilled workers will increase somewhat. On the contrary, reducing taxes on employment of unskilled will benefit this group, only. In spite of a barely discernible *aggregate* employment dividend in this case, the scheme can be of interest to policy makers searching a way to generate employment of unskilled workers.

We find no trade-off between welfare and unemployment concerns in the choice among revenue recycling alternatives. All the analysed schemes produce nearly the same, and positive, welfare effects. However, the welfare dividend is weak, i.e., the gains from recycling the revenue cannot offset the welfare cost of introducing market prices on CO_2 emissions. On the other hand, we do not calculate the welfare gain obtained in terms of a better environment and a positive contribution to climate stabilisation.

It is important to bear in mind that the primary objective of introducing the carbon permit system is to reduce emissions. Ideally, other policy aims like reducing unemployment require selective and targeted instruments in order to be addressed efficiently. No analyses of the Spanish unemployment problem put much emphasis on the payroll tax system as a major contributor to the problems. Our conclusions are relevant first of all to the Spanish carbon emission issue and have only minor potential as a contribution to the Spanish labour market debate. But still, if green taxes or tradable carbon permits are introduced, reducing payroll taxes can be a sensible way of recycling the revenue as this gives reduced unemployment rates as a positive side effect.

References

Bajo, O. and A.G. Gómez-Plana (1999): Efectos de cambios impositivos en un modelo de equilibrio general aplicado. *Revista Asturiana de Economía*, **15**: 23-42.

Bajo, O. and R. Salas (1998): Indices de concentración para la economía española: Análisis a partir de las fuentes tributarias. *Economía Industrial*, **320**: 101-116.

Balistreri, E. J. (2002): Operationalizing Equilibrium Unemployment: A General Equilibrium External Economies Approach. *Journal of Economic Dynamics & Control*, **26**: 347-374.

Ballard, C. L., J, B. Shoven and J. Whalley (1985): General equilibrium computation of the marginal welfare costs of taxes in the United States. *American Economic Review*, **75**: 128-138.

Bernstein, P. M., W. D. Montgomery, and T. F. Rutherford (1999): Global impacts of the Kyoto agreement: results from the MS-MRT model. *Resource and Energy Economics*, **21**: 375-413.

Biscourp, P. and C. Gianella (2001): Substitution and complementarity between capital, skilled and less skilled workers: an analysis at the firm level in the French manufacturing industry. Paper presented at European Association of Labour Economists 2001 Annual Conference, Jyväskylä.

Blanchard, O., J. F. Jimeno, J. Andrés, C. Bean, E. Malinvaud, A. Revenga, G. Saint-Paul, D. J. Snower, R. Solow, D. Taguas, and L. Toharia (1995): *Spanish Unemployment: Is There a Solution?*, Centre for Economic Policy Research, London.

Blau, F. D. and Kahn, L. W. (1999): Institutions and laws in the labor market. In O. Ashenfelter and D. Card (eds.) *Handbook of Labor Economics*, volume 3, Elsevier.

Bosello, F. and C. Carraro (2001): Recycling energy taxes: Impacts on a disaggregated labour market, *Energy Economics*, **23**: 569-594.

Bosquet, B. (2000): Environmental tax reform: does it work? A survey of the empirical evidence. *Ecological Economics*, **34**: 19-32.

Bovenberg, A. L and F. van der Ploeg (1998): Tax Reform, Structural Unemployment and the Environment, *Scandinavian Journal of Economics* 100 (3), 593-610.

Bover, O., P. Garcia-Perea and P. Portugal (2000): Iberian labour markets. Why Spain and Portugal are OECD outliers, *Economic Policy* October 2000.

Burda, M. and C. Wyplosz (1994): Gross worker and job flows in Europe. *European Economic Review*, **38**: 1287-1315.

Bye, B. (2000): Labour Market Rigidities and Environmental Tax Reforms: Welfare Effects of Different Regimes. In G. W. Harrison, S.E. Hougaard Jensen, L. Haagen Pedersen and T. F. Rutherford (eds.): *Using Dynamic General Equilibrium Models for Policy Analysis*, Elsevier Science B.V., Amsterdam.

Bye, B., S. Kverndokk and K. E. Rosendahl (2002): Mitigation costs, distributional effects, and ancillary benefits of carbon policies in the Nordic countries, the UK, and Ireland. *Mitigation and Adaptation Strategies for Global Change,* **7(4)**: 339-366.

Carraro, C., M. Galeotti, and M. Gallo (1996): Environmental taxation and unemployment: Some evidence on the ‘double dividend hypothesis’ in Europe. *Journal of Public Economics*, 62, pp. 141-181.

Castillo, S., J. F. Jimeno and O. Licandro (1998): Employment segmentation, labour mobility, and mismatch: Spain, 1987-1993. Working Paper 98-04, FEDEA, Madrid.

de Melo, J. and D. Tarr (1992): *A general equilibrium analysis of US foreign trade policy*. The MIT Press, Cambridge, MA.

Dolado, J. J., D. Gros and J. F. Jimeno (1998): La UEM y el mercado de trabajo en España: Costes y beneficios. Fundación Repsol, Madrid.

Dréze, J. and E. Malinvaud (1994): Growth and employment: the scope of a European initiative, European Economic Review, **38**: 489-504.

European Environment Agency (2004): Annual European Community greenhouse gas inventory 1990-2002 and inventory report 2004. EEA Technical report 2/2004, Copenhagen.

Fallon, P. and D. Verry (1988): The Economics of Labour Markets. Philip Allan, Hertfordshire, England.

Fæhn, T. and L.A. Grünfeld (1999): Recent Leaps Towards Free Trade - The Impact on Norwegian Industry and Trade Patterns, Journal of Policy Modeling, 21(6) 715-745

García, I. and J. A. Molina (1998): Household labour supply with rationing in Spain. *Applied Economics*, **30**: 1557-1570.

Gómez-Plana, A. G. (2001): Extensiones de la Matriz de Contabilidad Social de España. *Estadística Española*, **147**: 125-163.

Goulder, L. H. (1995): Environmental Taxation and the 'Double Dividend': A Reader's Guide, *International Tax and Public Finance*, 2 (2), 157-83.

Hamermesh, D. S. (1993): *Labor Demand*. Princeton University Press, Princeton.

Harberger, A. C. (1972): The Incidence of the Corporation Income Tax. *Journal of Political Economy*, **70**: 215-240.

Hertel, T. W. (ed.) (1997): *Global Trade Analysis. Modelling and Applications*. Cambridge University Press, Cambridge.

Holmøy, E (1992): The structure and working of MSG-5, an applied general equilibrium model of the Norwegian economy, in Bergman, L. and Ø. Olsen (eds): *Economic modeling in the Nordic countries, contributions to economic analysis* **210**, Elsevier Science (North-Holland).

Howe, H. (1975): Development of the extended linear expenditure system from simple saving assumptions. *European Economic Review*, **6**: 305-310.

Huergo, E. (1998): “Identificación del poder de Mercado: Estimaciones para la industria española”. Investigaciones Económicas **22**: 69-91.

IEA (1993a): *Energy Statistics of OECD countries 1990-1991*. International Energy Agency, OECD, Paris.

IEA (1993b): *Energy Balances of OECD countries 1990-1991*. International Energy Agency, OECD, Paris.

IPCC (2001): *Climate Change 2001: Mitigation*. Contribution of Working Group III to the Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), Cambridge University Press.

Kemfert, C. and H. Welsch (2000): Energy-Capital-Labor Substitution and the Economic Effects of CO_2 Abatement: Evidence for Germany. *Journal of Policy Modeling*, **22**: 641-660.

Majocchi, A. (1996): Green Fiscal Reform and Employment: A Survey. *Environmental and Resource Economics*, **8**: 375-397.

Markusen, J. R. (1990): Micro-foundations of external economies. *Canadian Journal of Economics*, **23**: 495-508.

Mathiesen, L. (1985): Computation of economic equilibria by a sequence of linear complementary problems. *Mathematical Programming Study*, **23**: 144-162.

McConnel, C. R., S. L. Brue and D. Macpherson (1999): *Contemporary Labor Economics*. 5Th edition. McGraw-Hill, Boston.

Mors, M. (1995): Employment, revenues and resource taxes: genuine link or spurious coalition?. *Int. J. Environment and Pollution*, **5**: 118-134.

Petrongolo, B., C. A. Pissarides (2001): Looking into the black box: A survey of the matching function. *Journal of Economic Literature*, **39**: 390-431.

Rutherford, T. F. (1999): Applied general equilibrium modeling with MPSGE as a GAMS subsystem: An overview of the modeling framework and syntax. *Computational Economics*, **14**: 1-46.

Rutherford, T. F. and S. Paltsev (2000): GTAP-Energy in GAMS: The Dataset and Static Model. Working Paper 00-02, Department of Economics, University of Colorado, Boulder.

Schöb, R. (2003): The Double Dividend Hypothesis of Environmental Taxes: A Survey, Working paper 60.2003, Fondazione Eni Enrico Mattei, Milano, http://www.feem.it/Feem/Pub/Publications/WPapers/default.htm

Toharia, L. (1996): "Empleo y paro en España: Evolución, situación y perspectivas", Ekonomiaz, **35:** 36-67.

Uriel, E., P. Beneito, F. J. Ferri and M. L. Moltó (1997): Matriz de Contabilidad Social de España 1990 (MCS-90). Instituto Nacional de Estadística, Madrid.

Figures and tables

Table 1. Classification of sectors

	Sectors
1	Agriculture
2	Coal
3	Oil
4	Gas
5	Electricity
6	Water and other energy sources
7	Nonenergy minerals, chemicals
8	Metal and machinery
9	Other manufacturing
10	Construction
11	Commerce and hotel trade
12	Road transport
13	Other transport and communications
14	Finance and insurance
15	House renting
16	Other services

Table 2: The pure abatement effects, and the recycling effects of different schemes

	Table 2a: Pure abatement effects	Table 2b: Recycling effects;			
	% change from benchmark	% change from Case A			
	Case A	Case B	Case C	Case D	Case E
Unemployment rate skilled	0.01	-0.33	-0.05	0.19	-0.99
Unemployment rate unskilled	-0.02	-0.20	-0.03	-0.42	0.11
Unemployment rate (agg)	0.00	-0.24	-0.04	-0.08	-0.44
Employment skilled	-0.01	0.54	0.07	-0.32	1.65
Employment unskilled	0.06	0.51	0.07	1.10	-0.31
Employment (agg)	0.03	0.52	0.07	0.49	0.53
Labour supply skilled	-0.01	0.50	0.06	-0.30	1.53
Labour supply unskilled	0.05	0.47	0.06	1.00	-0.27
Labour supply (agg)	0.03	0.48	0.06	0.48	0.45
Welfare	-0.93	0.48	0.53	0.47	0.48
market wage rate skilled	-2.69	3.04	0.62	0.65	6.21
market wage rate unskilled	-2.49	3.08	0.63	4.76	0.77
Capital rent	-2.40	0.28	0.73	0.22	0.34

Table 3: Sensitivity of results in Case E: 25% CO_2 abatement and skilled pay roll tax recycling

	Base Case	Sensitivity tests	
	Case E	CRTS & perfect competition	Constant returns in matching function
Unemployment rate skilled	-0.98	-1.00	-0.24
Unemployment rate unskilled	0.09	0.11	0.03
Unemployment rate (agg)	-0.44	-0.45	-0.30
Employment skilled	1.64	1.68	1.55
Employment unskilled	-0.25	-0.28	-0.23
Employment (agg)	0.56	0.56	0.53
Labour supply skilled	1.52	1.56	1.52
Labour supply unskilled	-0.22	-0.26	-0.22
Labour supply (agg)	0.48	0.47	0.48
Welfare	-0.46	-0.36	-0.47
market wage rate skilled	3.52	3.96	3.56
market wage rate unskilled	-1.72	-1.53	-1.76
Capital rent	-2.06	-1.95	-2.07

Figure 1: Nesting structure for production[14]

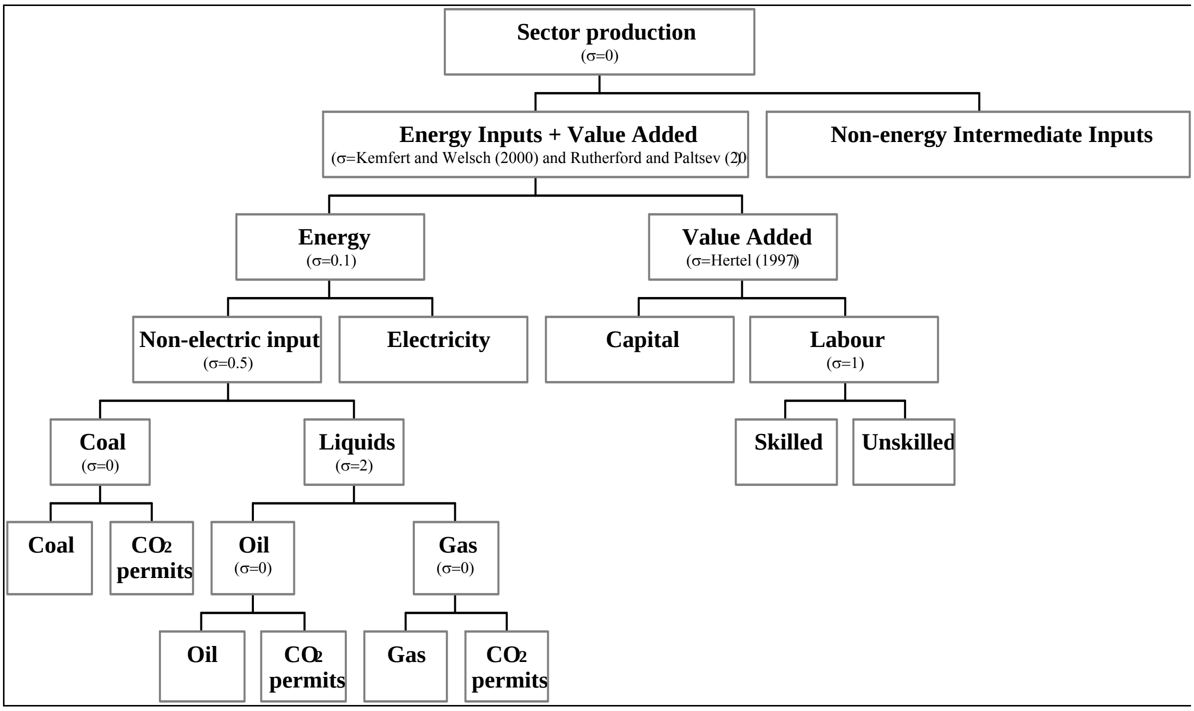
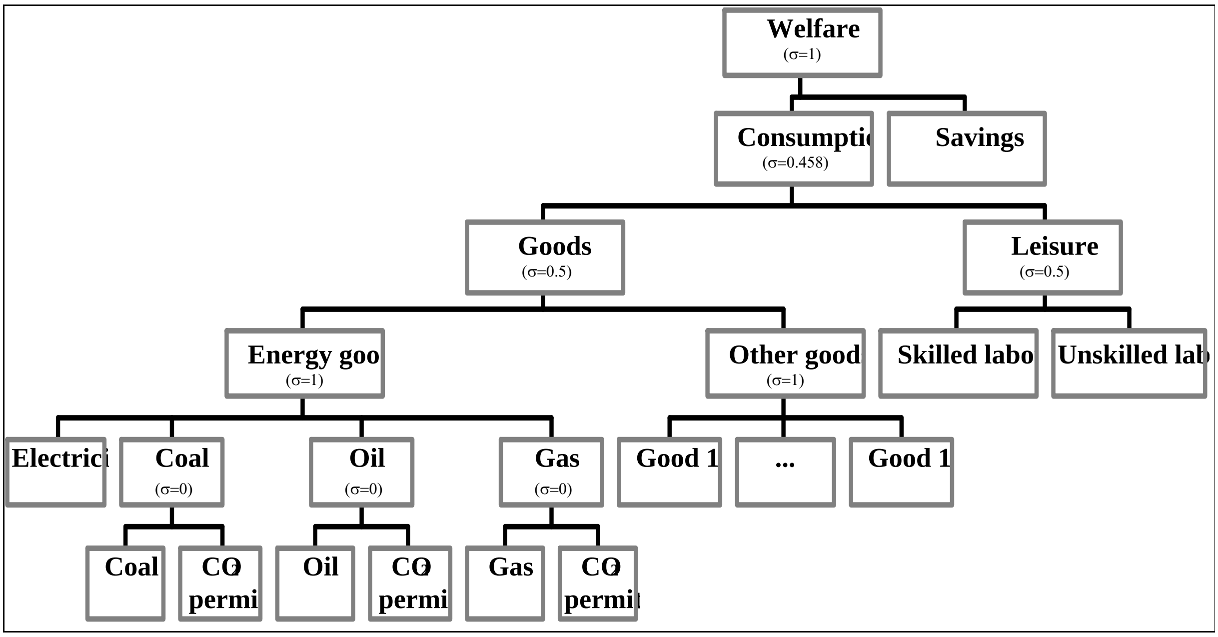


Figure 2: Nesting structure for consumption[15]



[14] The elasticity of substitution, σ, represents the substitution among components immediately below.

[15] The elasticity of substitution, σ, represents the substitution among components immediately below.

Figure 3: The Labour market loci (LL) and Trade balance loci (DD) in Case 0 (benchmark), Case A, Case B and Case C

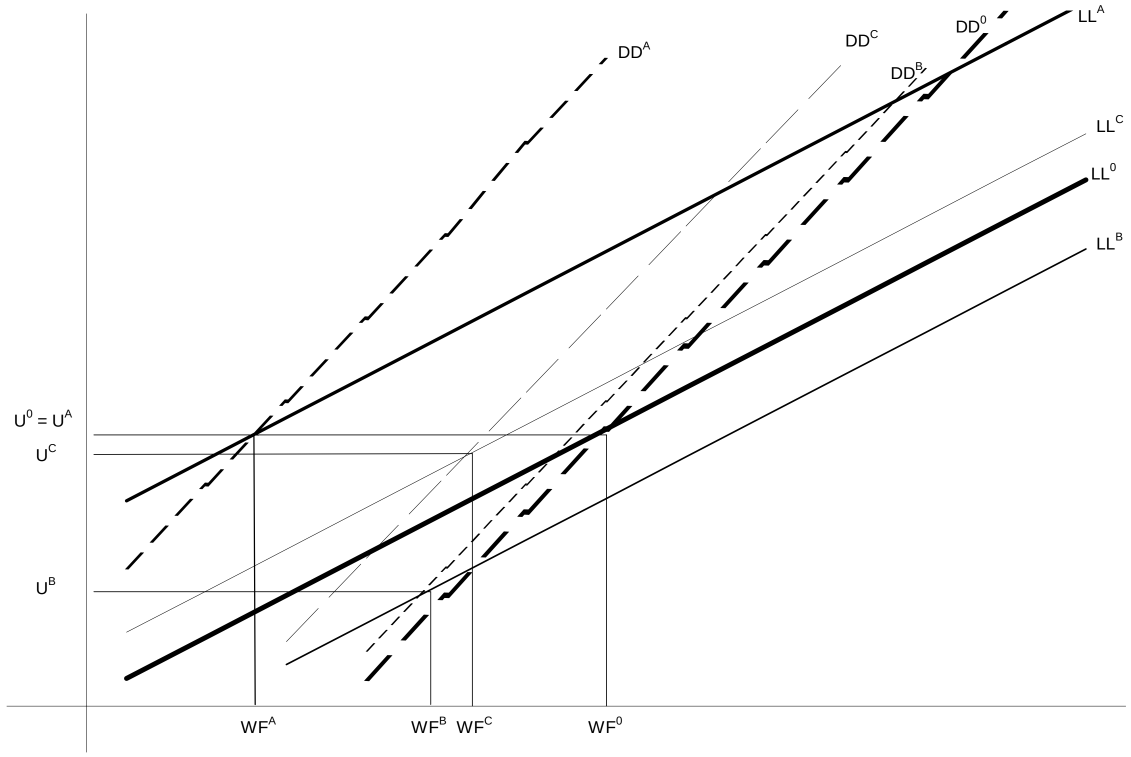
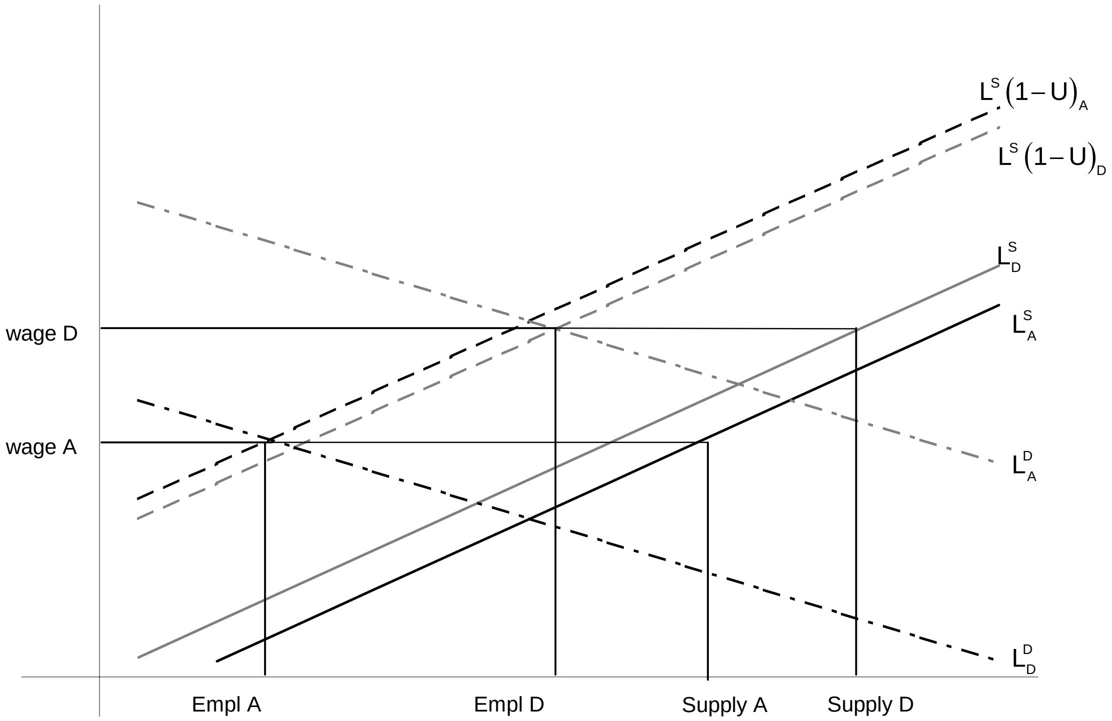
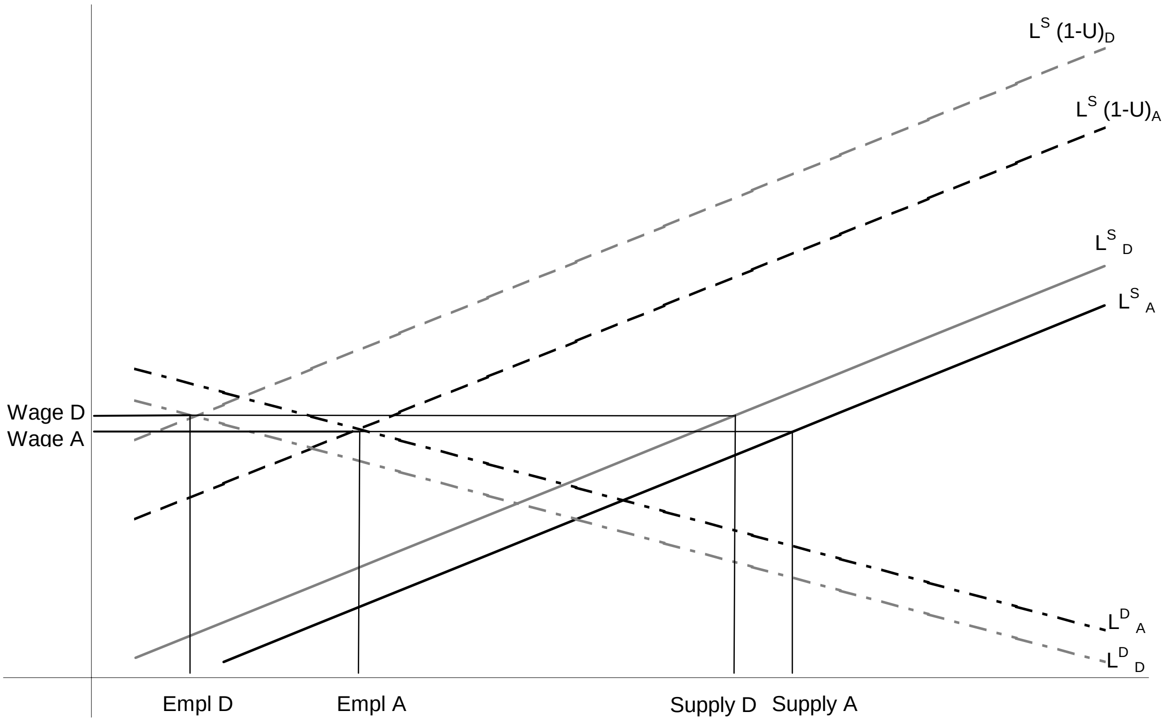


Figure 4: Effects of recycling through payroll tax for unskilled (Case D vs. Case A)

4A: Labour market for unskilled:



4B: Labour market for skilled:



Appendix 1

Notation

As a general rule, the notation in the model is as follows: endogenous variables are denoted by capital letters, exogenous variables by capital letters with a bar, and parameters by small Latin and Greek letters. There are *n* (*i,j=1,…,n=16*) production sectors, where good *n* is referred to the public sector and there are two subsets: *fuel* (representing coal, gas and oil) and *en* (representing electricity, coal, gas and oil).

Table A1: Endogenous variables

Symbol	**Definition**
A_i	Armington aggregate (total amount of goods supplied) of sector *I*
CARBON	Revenue from carbon permits
CF_i	Final domestic consumption of goods produced by sector *i*
$CO2^C_{fuel}$	CO_2 emissions from *fuel* combustion in final consumption
E_i	Number of firms in sector *I*
EXP_i	Exports of sector *I*
FC	Conversion factor of foreign currency into domestic currency
H^s, H^{us}	Inverse of the premium on reservation wages for skilled and un-skilled labour
I_i	Investment (gross capital formation) in goods produced by sector *I*
II_{ij}	Intermediate inputs from sector *j* used by sector *i*
IMP_i	Imports from sector *I*
IT_i	Revenue from tariffs on imports from sector *i*
$MARKUP_i$	Price-cost margin in sector *I*
NIT_i	Revenue from net indirect taxes in sector *i*
O_i	Production of sector *i* sold in the domestic market
P_{sav}	Shadow price of savings
PA_i	Unit cost of the Armington aggregate of sector *i*
PCARB	Unit cost of an emission permit
$PDIST_i$	Unit cost of of the distributed production of sector *i*
PE_i	Unit cost of energy of sector *I*
$PEVA_i$	Unit cost of energy and value added of sector *i*
PINV	Unit cost of aggregate investment
PL_i	Unit cost of labour used in sector *i*
$PLIQ_i$	Unit cost of liquids of sector *I*

Table A1 (cont.): Endogenous variables

POC_i	Unit cost of the production of sector *i* sold in the domestic market. It includes the permit price carbon emission for sectors coal, oil and gas
PO_i	Unit cost of the production of sector *i* sold in the domestic market
$PNEL_i$	Unit cost of non-electric energy of sector *i*
PVA_i	Unit cost of primary factors of sector *I*
PX_i	Price of effective production of sector *i*
Q_c	Demand for aggregate consumption
Q_{cg}	Demand for aggregate consumption of goods
Q_{fuel}	Demand for consumption of *fuel*
Q_{en}	Demand for consumption of good *en*
Q_{ocg}	Demand for other consumption goods
Q_l	Demand for leisure
Q_l^s, Q_l^{us}	Leisure associated to skilled and unskilled labour
Q_{sav}	Demand for savings
R	Capital rent
$SOCCE_i$	Revenue from social contributions payed by employers of sector *I*
$SOCCW_i$	Revenue from social contributions payed by employees of sector *i*
U^s, U^{us}	Unemployment rates of skilled and unskilled labour
W^s, W^{us}	Wages of skilled and unskilled labour
W_0^s, W_0^{us}	Reservation wages of skilled and unskilled labour
WF	Welfare
X_i	Effective production of sector *i*
Y_{RC}	Disposable income of the representative consumer
κ_i^d	Perceived elasticity of demand in sector *i*
Π_i^A	Unit profits for A_i (according to origin)
Π_i^{CET}	Unit profits for A_i (according to destination)
Π_i^X	Unit profits for X_i

Table A2: Exogenous variables and parameters

Symbol	Definition
$\overline{BALPUB}$	Balance of the public sector
$\overline{D}$	Trade balance surplus
$\overline{CF_n}$	Consumption of the public sector
$\overline{INVPUB}$	Investment of the public sector
$\overline{INVTOTAL}$	Total investment of the economy
$\overline{K_{RC}},\overline{K_G}$	Capital endowment for the representative consumer and public sector
$\overline{KF_i}$	Fixed requirements of capital in sector *I*
$\overline{L^s},\overline{L^{us}}$	Endowments of skilled and unskilled labour
$\overline{LF_i^s},\overline{LF_i^{us}}$	Fixed requirements of skilled and unskilled labour in sector *i*
$\overline{NTPS}$	Net transfers from the public sector, received by the representative consumer
$\overline{PFX}$	World prices
$\overline{SAVPUB}$	Savings of the public sector
$\overline{TOTCO2}$	Initial level of CO_2 emissions
$\overline{U^s},\overline{U^{us}}$	Unemployment rates of skilled and unskilled labour in the base year
$\overline{X_i}$	Effective production of sector *i* in the base year
$\overline{Y_G}$	Public sector income
$a1_i,\ldots,a6_i$, $b1$, $b2$, $b3_i$, c_{0i}, c_{ji}, d_i, e_i, g_{fuel}, h_{fuel}	Share parameters
it_i	*Ad valorem* tariff rates in sector *I*
nit_i	*Ad valorem* indirect taxes rates in sector *I*
$soccw^s_i$, $soccw^{us}_i$	*Ad valorem* social contributions rates paid by employees in sector *I*
$socce^s_i$, $socce^{us}_i$	*Ad valorem* social contributions rates paid by employers in sector *I*
Ω_i	Conjectural variations parameter in sector *I*
$\alpha1_i,\ldots,\alpha6_i$, ζ_i	Scale parameters
ε_i	Elasticity of transformation in sector *I*
η_0,η_1	Externalities from labour supply and unemployment
θ	Factor of abatement
σ_i^A	Armington elasticity of substitution in sector *I*
σ^{CL}	Elasticity of substitution between consumption and leisure
σ_i^{ELK}	Elasticity of substitution between energy inputs, labour and capital in sector *I*
σ_i^{LK}	Elasticity of substitution between labour and capital in sector *I*
τ_i,τ_{sav}	Share parameters

Equations

We present the complete set of equations included in the model. The general equilibrium model is solved as a mixed complementarity problem (see Mathiesen, 1985). Hence, it involves four sets of equations: zero profit conditions, market clearing equations in good and factor markets, budget constraints, and some additional constraints. The model core is a basic Arrow-Debreu model extended with some constraints and assumptions.

A2.1. Production

The base model presents increasing returns to scale due to some fixed costs, and a non-competitive pricing rule. Given that the upper nest is a Leontief function, the zero profit condition for each sector *i* is: *(i=1,…,16)*:

(A1) $$\Pi_i^X = PX_i - \frac{\left(R\overline{KF}_i + W^s\overline{LF_i^s} + W^{us}\overline{LF_i^{us}}\right)E_i}{X_i} - c_{0i}PEVA_i - \sum_{j=1}^{n(n\neq en)} c_{ji}PO_j = 0$$

According to the nested structure, there is a sequence of CES nests that defines the unit cost for the composite of energy and value added ($PEVA_i$). This nested sequence is ($i=1,\ldots,16$):

$$PEVA_i = \frac{1}{\alpha 1_i}\left(a1_i^{\sigma_i^{ELK}} PE_i^{1-\sigma_i^{ELK}} + (1-a1_i)^{\sigma_i^{ELK}} PVA_i^{1-\sigma_i^{ELK}}\right)^{\frac{1}{1-\sigma_i^{ELK}}}$$

$$PVA_i = \frac{1}{\alpha 2_i}\left(a2_i^{\sigma_i^{LK}} PL_i^{1-\sigma_i^{LK}} + (1-a2_i)^{\sigma_i^{LK}} R^{1-\sigma_i^{LK}}\right)^{\frac{1}{1-\sigma_i^{LK}}}$$

$$PL_i = \frac{1}{\alpha 3_i}\left(\frac{W^s\left(1+socce_i^s+soccw_i^s\right)}{a3_i}\right)^{a3_i}\left(\frac{W^{us}\left(1+socce_i^{us}+soccw_i^{us}\right)}{1-a3_i}\right)^{1-a3_i}$$

$$PE_i = \frac{1}{\alpha 4_i}\left(a4_i^{0.1} PNEL_i^{1-0.1} + (1-a4_i)^{0.1} PO_{elec}{}^{1-0.1}\right)^{\frac{1}{1-0.1}}$$

$$PNEL_i = \frac{1}{\alpha 5_i}\left(a5_i^{0.5} POC_{coal}^{1-0.5} + (1-a5_i)^{0.5} PLIQ_i^{1-0.5}\right)^{\frac{1}{1-0.5}}$$

$$PLIQ_i = \frac{1}{\alpha 6_i}\left(a6_i^2 POC_{oil}^{1-2} + (1-a6_i)^2 POC_{gas}^{1-2}\right)^{\frac{1}{1-2}}$$

$$POC_{fuel} = g_{fuel}\, PO_{fuel} + \left(1-g_{fuel}\right) PCARB, \qquad fuel=coal,\ oil,\ gas$$

We assume that the domestic producers maximize profits and select the optimal mix of domestic production and imports. They also maximize profits when deciding the share that is going to be sold in the domestic market and the share that is going to be exported. Both facts entails two zero profits functions (*i=1,…,16*):

(A2) $$\Pi_i^A = PA_i - \left(e_i^{\sigma_i^A} (PX_i(1+nit_i))_i^{1-\sigma_i^A} + (1-e_i)^{\sigma_i^A} \left(\overline{PFX}FC(1+it_i)\right)^{1-\sigma_i^A}\right)^{\frac{1}{1-\sigma_i^A}} = 0$$

(A3) $$\Pi_i^{CET} = PA_i - \frac{1}{\zeta_I}\left(d_i^{-\varepsilon_i} PO_i^{\varepsilon_i+1} + (1-d_i)^{-\varepsilon_i} \left(\overline{PFX}FC\right)^{\varepsilon_i+1}\right)^{\frac{1}{\varepsilon_i+1}} = 0$$

The previous zero profit conditions are used to derive demand functions. If we apply Shepard's Lemma on cost functions, we get unitary derived demands.

Next we introduce the corresponding market clearing equations. The left-hand side represents the demands, and right-hand side are supplies for all the markets included in the foregoing zero profit conditions (*i,j=1,…,16*):

(A4) $$X_i\left(-\frac{\partial \Pi_i^X}{\partial PO_j}\right) = II_{ji}$$

(A5) $$\sum_{i=1}^{n} E_i \overline{KF}_i + \sum_{i=1}^{n} X_i\left(-\frac{\partial \Pi_i^X}{\partial R}\right) = \overline{K_{RC}} + \overline{K_G}$$

(A6) $$\sum_{i=1}^{n} E_i \overline{LF_i^s} + \sum_{i=1}^{n} X_i \left(-\frac{\partial \Pi_i^X}{\partial W^s} \right) = \left(\overline{L^s} - Q_l^s \right)\left(1 - U^s\right)$$

(A7) $$\sum_{i=1}^{n} E_i \overline{LF_i^{us}} + \sum_{i=1}^{n} X_i \left(-\frac{\partial \Pi_i^X}{\partial W^{us}} \right) = \left(\overline{L^{us}} - Q_l^{us} \right)\left(1 - U^{us}\right)$$

(A8) $$A_i \left(-\frac{\partial \Pi_i^A}{\partial PX_i} \right) = X_i$$

(A9) $$A_i \left(-\frac{\partial \Pi_i^A}{\partial FC_i} \right) = IMP_i$$

(A10) $$A_i \left(-\frac{\partial \Pi_i^{CET}}{\partial PO_i} \right) = O_i$$

(A11) $$A_i \left(-\frac{\partial \Pi_i^{CET}}{\partial FC_i} \right) = EXP_i$$

(A12) $$X_i + IMP_i = O_i + EXP_i$$

(A13) $$I_i + \sum_{j=1}^{n} II_{ij} + CF_i = O_i$$

The markup function to cover fixed costs is *(i=1,…,16)*:

(A14) $$MARKUP_i = \frac{PX_i - c_{0i} PEVA_i - \sum_{j=1}^{n(n \neq en)} c_{ji} PO_j}{PX_i}$$

Which corresponds to the Lerner index:

(A15) $$MARKUP_i = \frac{\Omega_i}{E_i \kappa_i^d}$$

And:

(A16) $$\kappa_i^d = \sigma_i^A - \left(\sigma_i^A - 1\right)\frac{PX_i X_i}{\sum_{i=1}^{n} PX_i X_i}$$

A2.2. Consumption

The final demand functions are derived from the maximization of the representative consumer's nested welfare function (see Figure 2):

(A17) $$WF = \left(Q_c\right)^{1-\tau_{sav}}\left(Q_{sav}\right)^{\tau_{sav}}$$

subject to the budget constraints:

(A18) $$Y_{RC} = W^s\left(\overline{L^s} - Q_l^s\right)\left(1-U^s\right) + W^{us}\left(\overline{L^{us}} - Q_l^{us}\right)\left(1-U^{us}\right) + R\overline{K_{RC}} + \overline{NTPS}$$

(A19) $$Y_{RC} = P_{sav}\overline{Q_{sav}} + \sum_{i=1}^{n} PO_i CF_i + \sum_{fuel} PCARB\, CO2_{fuel}^{C}$$

where the nests in the welfare function are defined by:

(A20) $$Q_c = \left(b1^{\sigma^{CL}} Q_{cg}^{1-\sigma^{CL}} + (1-b1)^{\sigma^{CL}} Q_l^{1-\sigma^{CL}}\right)^{\frac{1}{1-\sigma^{CL}}}$$

(A21) $$Q_l = \left(b2^{0.5} Q_l^{s\,1-0.5} + (1-b2)^{0.5} Q_l^{us\,1-0.5}\right)^{\frac{1}{1-0.5}}$$

(A22) $$Q_{cg} = \left(b3_{en}^{0.1} Q_{en}^{1-0.1} + b3_{elec}^{0.1} Q_{elec}^{1-0.1} + b3_{ocg}^{0.1} Q_{ocg}^{1-0.1}\right)^{\frac{1}{1-0.1}}$$

(A23) $$Q_{en} = (Q_{coal})^{\tau_{coal}}(Q_{oil})^{\tau_{oil}}\left(Q_{gas}\right)^{\tau_{gas}}$$

(A24) $$Q_{fuel} = \left(\frac{CF_{fuel}}{h_{fuel}}, \frac{CO2_{fuel}^{C}}{1-h_{fuel}}\right),$$

(A25) $$Q_{ocg} = \prod_{i=1}^{n-1} CF_i^{\tau_i}\ , \qquad i \neq elec,coal,oil,gas$$

The resolution of the maximization problem yields demand functions for savings ($\overline{Q_{sav}}$), leisure for skilled labour ($Q^s{}_l$), leisure for unskilled labour ($Q^{us}{}_l$), final demand (CF_i) and carbon permits demand ($CO2^C_{fuel}$) that enter in equations (A37), (A6), (A7), (A13) and (A31), respectively.

A2.3. Public sector

The role of the public sector is to set and collect taxes. The income of this sector is:

(A26) $$\overline{Y_G} = R\overline{K_G} + \sum_{i=1}^{n}(SOCCE_i + SOCCW_i) + \sum_{i=1}^{n}(NIT_i + IT_i) + CARBON - \overline{NTPS}$$

where the public revenue comes from:

(A27) $$SOCCE_i = socce_i W^s X_i\left(-\frac{\partial \Pi_i^X}{\partial W^s}\right) + socce_i W^{us} X_i\left(-\frac{\partial \Pi_i^X}{\partial W^{us}}\right)$$

(A28) $$SOCCW_i = soccw_i W^s X_i\left(-\frac{\partial \Pi_i^X}{\partial W^s}\right) + soccw_i W^{us} X_i\left(-\frac{\partial \Pi_i^X}{\partial W^{us}}\right)$$

(A29) $$NIT_i = PDIST_i A_i\left(-\frac{\partial \Pi_i^A}{\partial PDIST_i}\right) nit_i$$

(A30) $$IT_i = \overline{PFX}\ FC\ A_i\left(-\frac{\partial \Pi_i^A}{\partial FC_i}\right) it_i$$

Moreover, the public sector can control CO_2 emissions through emission permits, where emissions come from production and consumption activities. The public sector can constrain the total level of emissions ($\overline{TOTCO2}$) through a factor of abatement (θ), which is equal to 1 in the benchmark. For example, a reduction in CO_2 emissions (i.e., reduction in the number of permits) of 25% means that θ is equal to 0.75. The next equation represents this mechanism:

(A31) $$\theta \ \overline{TOTCO2} = \sum_{i=1}^{n} X_i \left(-\frac{\partial \Pi_i^X}{\partial PCARB} \right) + \sum_{i=1}^{n} CO2_{fuel}^{C}, \qquad fuel=carbon,oil,gas$$

The public revenue accruing from the auction of permits/carbon taxation is:

(A32) $$CARBON = \sum_{i=1}^{n} X_i \left(-\frac{\partial \Pi_i^X}{\partial PCARB} \right) PCARB + \sum_{fuel} CO2_{fuel}^{C} PCARB, \quad fuel=carbon,oil,gas$$

Due to the assumption of neutrality regarding public sector activity, the macro closure rules are:

(A33) $$\overline{BALPUB} = \overline{SAVPUB} - \overline{INVPUB}$$

(A34) $$\overline{CF_n} = \overline{Y_G} - \overline{SAVPUB}$$

A2.4. Investment, savings and foreign sector

The macro closures involve some other constraints related to investment (equation (A35)) and the savings in the open economy (equations (A36) and (A37)):

(A35) $$\sum_{i=1}^{n} PO_i I_i \ = PINV\,\overline{INVTOTAL}$$

(A36) $$\sum_{i=1}^{n} \overline{PFX} \ EXP_i - \sum_{i=1}^{n} \overline{PFX} \ IMP_i = \overline{D}$$

(A37) $$P_{sav} Q_{sav} + \overline{SAVPUB} - PINV \ \ \overline{INVTOTAL} = \overline{D} \ \ FC$$

A2.5. Factor markets

The equilibrium in the capital market is represented by equation (A5). The market clearing conditions in labour markets are (A6) and (A7) with some restrictions related to the matching unemployment assumptions:

(A38) $$W^s = W_0^s \frac{1}{H^s}$$

(A39) $$W^{us} = W_0^{us} \frac{1}{H^{us}}$$

(A40) $$H^s = \left(1 - \overline{U^s}\right) \left(\frac{\sum_{i=1}^{n} X_i \left(-\frac{\partial \Pi_i^X}{\partial W^s} \right)}{\sum_{i=1}^{n} \overline{X}_i \left(-\frac{\partial \Pi_i^X}{\partial W^s} \right)} \right)^{\eta_0} \left(\frac{U^s}{\overline{\overline{U^s}}} \right)^{\eta_1}$$

(A41) $$H^{us} = \left(1 - \overline{U^{us}}\right) \left(\frac{\sum_{i=1}^{n} X_i \left(-\frac{\partial \Pi_i^X}{\partial W^{us}} \right)}{\sum_{i=1}^{n} \overline{X}_i \left(-\frac{\partial \Pi_i^X}{\partial W^{us}} \right)} \right)^{\eta_0} \left(\frac{U^{us}}{\overline{\overline{U^{us}}}} \right)^{\eta_1}$$

A2.6. Perfect competition

Assuming constant returns to scale (CRTS), the core of the model remains (production functions are defined in Figure 1). Nevertheless, some equations are replaced when the model is changed from the non-competitive version to the competitive one. The zero profit equation (A1') replaces equation (A1) *(i=1,…,16)*:

(A1') $$\Pi_i^X = PX_i - c_{0i} PEVA_i - \sum_{j=1}^{n(n \neq en)} c_{ji} PO_j = 0, \quad i=1,\dots,16$$

In the CRTS version, there are no fixed costs of primary factors, and we must replace market-clearing conditions (A5) to (A7) by:

(A5') $$\sum_{i=1}^{n} X_i \left(-\frac{\partial \Pi_i^X}{\partial R} \right) = \overline{K_{RC}} + \overline{K_G}$$

(A6') $$\sum_{i=1}^{n} X_i \left(-\frac{\partial \Pi_i^X}{\partial W^s} \right) = \left(\overline{L^s} - Q_l^s\right)\left(1 - U^s\right)$$

(A7') $$\sum_{i=1}^{n} X_i \left(-\frac{\partial \Pi_i^X}{\partial W^{us}} \right) = \left(\overline{L^{us}} - Q_l^{us}\right)\left(1 - U^{us}\right)$$

Calibration and data

The model has been calibrated using the Spanish Social Accounting Matrix for 1990 MCS-90 developed in Uriel *et al*. (1997) and Gómez-Plana (2001). The matrix represents the benchmark equilibrium of the model. Calibration is made in three steps. In the first step, the matrix collects the quantities appearing in the equations, that means a first reference point in the isoquant of the calibrated function. In the second step, relative prices in 1990 fix the slope of the isoquant in that point. Since matrix data do not distinguish between prices and quantities, only showing values, we follow Harberger's (1972) assumption and choose the quantity units for goods and factors so that prices are unitary. The last step in the calibration uses elasticities, which show the curvature of the isoquant. To sum up, we have the slope and curvature for a point in each isoquant, and from there, all the unknown parameters are calibrated using Rutherford's (1999) method.

Elasticities pay a key role in this model due to the calibration method applied. Therefore a careful research for the benchmark values has been performed. The nested structure of the production technology (see Section 2.2) follows Rutherford and Paltsev's (2000) CGE model, with some additional information (see Table A3): elasticities of substitution between labour and capital σ_i^{LK}, as well as Armington elasticities σ_i^{A} are taken from GTAP (Hertel, 1997). The available evidence shows quite different figures for elasticities of substitution between skilled and unskilled labour σ_i^{LL}, which may range from more than 5 to (small) negative values; see Hamermesh (1993), Chapter 3. The simulations have been performed using a "low" value of 1, which would agree with the recent estimates of Biscourp and Gianella (2001) for French manufacturing. Elasticities of substitution between energy and value added σ_i^{E-LK} for manufactures are taken from Kemfert and Welsch (2000). Finally, elasticities of transformation ε_I come from de Melo and Tarr (1992).

Table A3: Elasticities and Herfindahl indexes[16]

	SECTORS	σ_i^{LK}	σ_i^{A}	ε_i	σ_i^{E-LK}	$1/E_i$
1	Agriculture	0.56	2.2	3.9	0.5	0,00154
2	Coal	1.12	2.8	2.9	0.5	0,06716
3	Oil	1.12	2.8	2.9	0.5	0,32994
4	Gas	1.12	2.8	2.9	0.5	0,08997
5	Electricity	1.26	2.8	2.9	0.5	0,08997
6	Water and other energy sources	1.26	2.8	2.9	0.5	0,05095
7	Nonenergy minerals, chemicals	1.26	1.9	2.9	0.96	0,03533
8	Metal and machinery	1.26	2.8	2.9	0.88	0,04666
9	Other manufacturing	1.26	2.8	2.9	0.70	0,01404
10	Construction	1.40	1.9	0.7	0.5	0,00572
11	Commerce and hotel trade	1.68	1.9	0.7	0.5	0,01790
12	Road transport	1.68	1.9	0.7	0.5	0,00637
13	Other transport and communications	1.68	1.9	0.7	0.5	0,33973
14	Finance and insurance	1.26	1.9	0.7	0.5	0,03855
15	House renting	1.26	1.9	0.7	0.5	0,00127
16	Other services	1.26	1.9	0.7	0.5	0,00799

The elasticities of substitution for consumption also follow Rutherford and Paltsev (2000) with some additions and changes. The elasticity of substitution between leisure and consumption σ_h^{LQ} has been obtained using the procedure of Ballard *et al*. (1985), from the uncompensated elasticity of labour supply estimated in García and Molina (1998)[17]. A total of 40 hours worked per week, out of a potential 70, has been assumed. We have no data available on the elasticities of substitution between leisure for the skilled and leisure for the unskilled σ_h^{LEI}, so we assume they take a constant value across households of 0.5.

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16 σ_i^{LK} and σ_i^{A} : Hertel (1997).

$_i$: de Melo and Tarr (1992).

σ_i^{E-LK} : Kemfert and Welsch (2000) and Rutherford and Paltsev (2000).

1/E$_I$: Elaborated from Bajo and Salas (1998).

17 They estimate the elasticity of labour supply with respect to the own wage, for both men and women, from different functional forms. Since they find no evidence against the null hypothesis that these elasticities are zero, we use this value as starting point when computing σ_h^{LQ}.

Table A4: Consumption of fuels[18]

	SECTORS	COAL	OIL	GAS	ELECTRICITY	TOTAL
1	Agriculture	0.01	1.37	0.03	0.3	1.72
2	Coal[19]	0.76	0	0	0	0.76
3	Oil[20]	0	4.20	0	0.17	4.37
4	Gas[21]	0.01	0.06	0.10[22]	0	0.17
5	Electricity[23]	14.11	2.18	0.27	1.96[24]	18.52
6	Water and other energy sources	0	0	0	0	0
7	Non-energy minerals, chemicals[25]	3.79	6.98	2.38	3.15	16.30
8	Metal and machinery[26]	0.09	0.31	0.35	0.63	1.38
9	Other manufacturing[27]	0.45	1.58	1.01	1.59	4.63
10	Construction	0	0.05	0	0.07	0.11
11	Commerce and hotel trade[28]	0.01	0.47	0.08	0.96	1.53
12	Road transport	0	18.05	0	0	18.05
13	Other transport & communications[29]	0	4.47	0	0.32	4.78
14	Finance and insurance[11]	0.00	0.26	0.05	0.52	0.83
15	House renting	0	0	0	0	0
16	Other services[11]	0.01	0.33	0.06	0.67	1.07
	Final consumption by households[30]	0.28	3.65	0.64	2.60	7.17

Source: Energy Balances of OECD Countries 1990-1991, OECD, Paris, 1993.

Benchmark emission levels are calibrated in the CGE model in the usual way (i.e., Bernstein *et al.*, 1999). IEA (1993a) provides data on consumption of fuels. We aggregate according to sectors and types of fuels displayed in our model (see Table A4). Then, we transform all variables in a common unity, EJ (displayed in Table A5), using Spanish specific conversion factors (see IEA, 1993b). Finally,

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[18] Units: Million metric tons of oil equivalent. Non-energy use is not included.

[19] In table: Coal transformation + Own use

[20] In table: Petroleum Refineries (Crude oil – petroleum products) + Own use + Distribution losses

[21] In table: Gas Works

[22] In table: Own use + Distribution losses – gas produces (gas works)

[23] In table: Public electricity + CHP + Autoproducers of Electricity + CHP

[24] In table: Own use + Distribution losses

[25] In table: Iron and Steel + Non-ferrous Metals + Chemicals and Petrochemical + Non-metallic Minerals + Mining and Quarrying

[26] In table: Transport equipment + Machinery

[27] In table: Food and Tobacco + Paper, Pulp and Printing + Wood and Wood Products + Textile and Leather + Non specified

[28] In table: Commerce and Public Services divided according to SAM weights based on production.

[29] In table: Air + Rail + Internal Navigation

[30] In table: Residental

we find CO_2 emissions at sectoral level by multiplying fuels consumption in EJ by emission coefficients. Emission coefficients, transforming from EJ to mt. of CO_2, for coal (0.024), gas (0.0137) and oil (0.0181) are taken from Rutherford and Paltsev (2000).

Table A5: Consumption of fuels in EJ

	SECTORS	COAL	OIL	GAS	TOTAL
1	Agriculture	0,0004168	0,0571016	0,0012504	0,0587688
2	Coal	0,0316768	0,0000000	0,0000000	0,0316768
3	Oil	0,0000000	0,1750560	0,0000000	0,1750560
4	Gas	0,0004168	0,0025008	0,0041680	0,0070856
5	Electricity	0,5881048	0,0908624	0,0112536	0,6902208
6	Water and other energy sources	0,0000000	0,0000000	0,0000000	0,0000000
7	Non-energy minerals, chemicals	0,1579672	0,2909264	0,0991984	0,5480920
8	Metal and machinery	0,0037512	0,0129208	0,0145880	0,0312600
9	Other manufacturing	0,0187560	0,0658544	0,0420968	0,1267072
10	Construction	0,0000000	0,0020840	0,0000000	0,0020840
11	Commerce and hotel trade	0,0004168	0,0195896	0,0033344	0,0233408
12	Road transport	0,0000000	0,7523240	0,0000000	0,7523240
13	Other transport & communications	0,0000000	0,1863096	0,0000000	0,1863096
14	Finance and insurance	0,0000000	0,0108368	0,0020840	0,0129208
15	House renting	0,0000000	0,0000000	0,0000000	0,0000000
16	Other service	0,0004168	0,0137544	0,0025008	0,0166720
	Final consumption by households	0,0116704	0,1521320	0,0266752	0,1904776
	Total	0,8135936	1,8322528	0,2071496	2,8529960

The specification of the search costs requires values for two externalities. When it comes to matching functions, we have some evidence for Spain in Burda and Wyplosz (1994) and Castillo *et al*. (1998). The first study proves the no existence of constant returns to scale in the matching function and its estimations yields a value of 0.14 for η_0, and of 0.12 for η_1. On the other hand, Castillo *et al*. (1998) provide a value of 0.15 for η_0, and 0.85 for η_1. In the reference scenario, we use the values from the first study. However, the other values are used in a sensitivity analysis.

The data on imperfect competition are taken from Bajo and Salas (1998), who compute concentration indices using data on sales for more than two million Spanish firms, obtained from official VAT returns. Firms include all sectors, and not only manufactures as they are commonly estimated in literature. The indexes are displayed in Table A3.

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